SUPERCONDUCTING ELECTRONICS, P. 34

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Newslog

FEB 4. Motorola Inc., Schaumburg, Ill., said it had signed a contract to have **Krunichev Enterprise,** a Russian aerospace company, launch 21 of the 73 satellites that will form Motorola's Iridium global communications network. Krunichev will launch the satellites on three Proton rockets, each carrying seven satellites.

FEB 8. Conductus Inc., Sunnyvale, Calif., said it had developed a 32-bit shift register from the high-temperature superconductor yttrium barium copper oxide. The chip, containing 64 Josephson junctions—superconducting counterparts to transistors—operates at 120 GHz, 2000 times the speed of processor chips in today's fastest PCs. Its developers claim the circuit is the fastest ever made.

FEB 9. Brazil's National Institute for Space Research said its first satellite, SCD-1, had been launched by **Orbital Sciences Corp.**, Fairfax, Va., from the Kennedy Space Center at Cape Canaveral, Fla. The Pegasus rocket used was launched from a B-52 bomber. Orbiting 750 km above the earth, the satellite will collect environmental data about the Amazonian rainforest.

FEB 9. Southwestern Bell Corp., St. Louis, said it had acquired two cable systems in the Washington, D.C., area from **Hauser Communications Inc.**, New York City, for US $650 million. Analysts said the move was the first by a telephone company into the cable television business. Southwestern plans to use the acquisitions to experiment with ways to apply advances in phone technology to a cable system. The purchase still requires regulatory approval.

FEB 9. Steven P. Jobs, founder of **NeXT Computer Inc.**, Freemont, Calif., said he was abandoning the company's computer business to concentrate instead on selling its Nextstep PC operating software. The move puts the company in direct competition with **Microsoft Corp.**, Redmond, Wash. NeXT will also sell its hardware design center to **Canon Inc.**, Tokyo, which was the company's first outside investor.

FEB 11. A special **Federal Communications Commission** (FCC) panel said there were flaws in all five of the systems competing to be picked as the U.S. high-definition television standard. It recommended that the FCC's **Advisory Committee on Advanced Television** hold a new round of testing after the four groups with digital systems reported they had fixed the problems. Analysts said the advisory committee's final decision may be postponed for about five months. Officials from all four groups said they had begun talking about merging their systems into one—an idea that the FCC committee has been promoting. The fifth, nondigital, contender dropped out.

FEB 12. Russia's deputy nuclear energy minister said Russia had agreed to construct two nuclear power plants in **Iran** based on an improved version of the Soviet-designed VVER pressurized-water reactor. While weapons-grade material could be produced from the plant's spent fuel, Iran has pledged to abide by international supervision and nonproliferation norms.

FEB 12. The **U. S. government** said it had signed an agreement with **Argentina** that will permit that country to buy advanced computer equipment and nuclear technology. Under the deal, Argentina agreed to a broad range of controls over technology it develops and technology it receives from the United States. The agreement—the first such U.S. deal with a Latin American country—follows Argentina's ending of its Condor II ballistic missile program and its imposition of export restrictions on dangerous technology to hostile countries.

FEB 18. The European Community's (EC's) commissioner of industry and technology said that he had recommended that the EC drop its plan to develop its HD-Mac technology for high-definition television. With the action, the EC acknowledged that more advanced digital systems under consideration in the United States would almost certainly become the worldwide standard.

FEB 20. Japan's Institute of Space and Astronautical Science said it had launched its Astro-D satellite from Kagoshima Space Center on Kyushu. Developed in cooperation with the United States, the satellite will be used to detect X-rays from celestial bodies, supply a detailed breakdown of specific frequencies, and provide clues to the composition of distant objects as well as their temperatures and velocities.

FEB 22. The **Clinton administration** announced a broad new technology initiative that calls for spending $17 billion over four years and shifting billions of dollars from military research programs to private industry. The strategy relies on far greater industry involvement in choosing how to spend some government research dollars, and funds a variety of projects in manufacturing, next-generation automobiles, and computer networks.

FEB 22. Ameritech Inc., Chicago, said it had unveiled a plan for introducing competition into the U.S. local telecommunications market, which it will file with the FCC. The plan would open up Ameritech's local telephone network to competition by separating its transport and switching services. In return, the company said it would seek drastic changes in its operating environment, including the ability to provide long-distance services. The plan is believed to be the first such proposal by a Baby Bell company. But two weeks earlier, independent **Rochester Telephone Corp.** had filed a similar plan with New York State regulators to open up the local phone market.

FEB 23. AT&T Co. said it had signed a partnership agreement with **China's State Planning Commission** to study possible investments in a wide range of telecommunications equipment, phone and data transmission services, and corporate communications networks. China's goal is to have 100 million phone lines by the year 2000; it currently has 30 million.

MAR 5. Lawrence Livermore National Laboratory, Livermore, Calif., confirmed that earlier this year it had picked **Meiko Scientific Corp.**, a small British-owned company in Waltham, Mass., over several U.S. companies to provide a new $15 million massively parallel supercomputer. Meiko is believed to be the only non-U.S.-owned company to sell a supercomputer to a U.S. government laboratory in 30 years. Lawrence Livermore said that Meiko's computer products are substantially designed and built in the United States.

Preview:

APR 23. By this date, the **Environmental Protection Agency** (EPA), Washington, D.C., must issue its final rule concerning ozone-depleting chlorofluorocarbons (CFCs) to expand on a provision of the 1990 Clean Air Act. The rule covers the EPA certification of recovery and recycling equipment before the equipment is used to remove CFCs.

COORDINATOR: Sally Cahur

APRIL 1993 Volume 30 Number 4

IEEE SPECTRUM

RETROSPECTIVE

National Aeronautics and Space Administration

IEEE AWARDS

Cover: The pair of eyes peering out to see how engineers view themselves was first photographed by Michael Hirst. This photo, in turn, was then photographed by Bill Simone as a still life framed by torn paper. Gus Sauter did the cover design. See p. 24.

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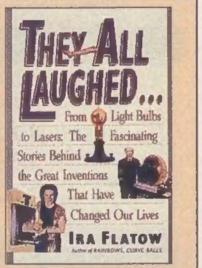
Books

The lighter side of invention

Steven J. Frank



They All Laughed... From Light Bulbs to Lasers: The Fascinating Stories Behind the Great Inventions That Have Changed Our lives. *Flatow, Ira, HarperCollins, New York, 1992, 240 pp., US $20.*

The life cycle of any technical company begins with an idea, an invention—something that solves a problem more quickly, more cheaply, or with less fuss than before. It is seldom a new problem. The fresh approach probably makes no headlines. And by the time the originator is through haggling with patent lawyers and justifying his invention to investors and production engineers, the rest of the world may already have caught up. Market success will require further innovation: performance improvements, fine tuning, added efficiencies—and some luck.

Of course, such practicality hardly squares with the Hollywood version of invention. While innovators everywhere receive praise, admiration, and (occasionally) financial reward for their efforts, only in the United States are tinkerers elevated into folk heroes. The standard folk tale has important breakthroughs hiding in an eccentric's neural recesses until they suddenly spring forth in a flash of genius. Unable to escape obsession even for a moment, the tormented pioneer is propelled into his garage to toil without rest until his secret dream becomes reality. One day he lifts the door to reveal the new mousetrap or massively parallel computer, as the case may be. The public, skeptical at first, soon explodes with enthusiasm.

In recounting the human and, to a lesser extent, technical stories behind a host of legendary innovations, award-winning journalist Ira Flatow shows how difficult it is to generalize about inventors or the spirit behind their works. In this engaging book, he describes 23 inventions from various technical disciplines and time periods. One of my favorites is the facsimile machine, whose cumbersome electromechanical antecedents predated the telephone by three decades [see "Facsimile's false starts," by Jonathan Coopersmith, *IEEE Spectrum*, February, pp. 46–49].

What emerges from these highly dissimilar portraits is the sense that most inventors do indeed combine patience, skill, and pragmatism with an intense, sometimes romantic refusal to give up. But even that picture can prove simplistic. Pathbreakers usually build on the work of others before them; rarely does genius come without a pedigree. Flatow forces us to reconsider the very idea of invention in a world where difficult puzzles often attract the attention of many minds.

Who *really* invented television?, he asks. Was it Dr. Paul Nipkow, the young German researcher who used spinning disks and photocells to electrically encode, transmit, and re-create moving images? Or John Logie Baird, who improved Nipkow's system and brought a commercial version to the British public? Or was it Philo T. Farnsworth, of the United States, who recognized the limits of

Books

mechanical systems and built the first fully electrical system? Each owed his own advance, at least in part, to the contributions of others before him.

In other instances, curiosity plays a key role. When Constantine Fahlberg noticed an unusually sweet tinge to his dinner in 1879, he realized some substance from his laboratory must have remained on his hands. Returning to the lab and tasting the contents of bottle after bottle of chemicals (not a widely recommended procedure, mind you), he finally identified the sugary culprit and named it saccharin. In cases like this, invention begins to look more like accidental discovery.

Does any of this really matter? If it is so difficult to define invention and identify the true inventor, perhaps we should simply shun such questions entirely. But money usually follows success, and that is when lawyers and judges get into the act. The first to invent wins both the glory and the purse.

On the serious side, *They All Laughed...* shows us how great inventions often spawn pitched legal battles, and more importantly, how arbitrary the outcomes can be. When even science professionals have trouble distinguishing true invention from routine improvement, or bestowing recognition on its most rightful recipient, how can the legal system hope to do any better?

As pure entertainment, Flatow's well-researched stories do not disappoint. Narrated swiftly and with keen attention to the ironies of serendipity and a fickle public, the book is a highly readable account of the inventors, their eccentricities, and the ultimate impact of their creations on society. Flatow shows us how real inventors elude contrived stereotype. Some are driven, some lucky, some just doing their jobs—but all help define the essence of innovation on which technological progress ultimately depends.

Steven J. Frank (M) is a patent attorney with the firm of Cesari and McKenna in Boston. He is the author of Learning the Law: Success in Law School & Beyond, *published last year by Carol Publishing Group in New York.*

Mathematics made dilettantish

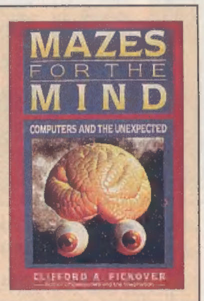
Reuben Hersh

"This book is designed to shatter your mind," announces the preface. It is not clear whether this objective is to be accomplished by reading the whole book, or if a few pages will suffice.

After a preface, there are 78 chapters, two appendices, and dozens of black-and-white reproductions of computer graphics. Each chapter is divided into as many as 15 pieces. You do not need a computer to figure out that each chapter, and especially each of the chapter pieces, must be awfully short.

Computer graphics hobbyists may find the

Mazes for the Mind: Computers and the Unexpected.
Pickover, Clifford A., St. Martin's Press, New York, 1992, 428 pp., $32.95.



book interesting. Pickover offers lots of ideas for funny things you can do on your monitor. Details on how to do them, though, are skimpy.

Section 34.3 (chapter 34, section 3) concerns "Strange Toilet Paper." In that section I was referred back to 34.1, "The Length of a Roll of Toilet Paper." It seems, not surprisingly, that if you measure the thickness of your paper, the diameter of your roll, and the size of the hole in the middle, then, with the help of some simple algebra, you can figure out how long the paper would be if you were stupid enough to unroll it.

Chapter 35 is devoted to "Bertrand Russell's Twenty Favorite Words." Pickover

(Continued on p. 12)

Innovations

Parallel, circular beam shines from solid-state laser

Semiconductor lasers to date have produced a beam that is elliptical in cross section and diverges by about 30 degrees. But the beam of a redesigned semiconductor laser is nearly cylindrical, and diverges by less than half a degree. Optical-fiber communications and optical memories both stand to benefit: the narrower and the more circularly symmetric the beam is, the more light can be coupled into the core of an optical fiber or the smaller the spot it can write.

The team that designed the laser and demonstrated it last year included groups from three institutions, all in New York State. Dennis G. Hall and his colleagues at the University of Rochester's Institute of Optics directed collaborators from IBM Corp.'s Thomas J. Watson Research Center in Yorktown Heights and Cornell University's National Nanofabrication Facility in Ithaca.

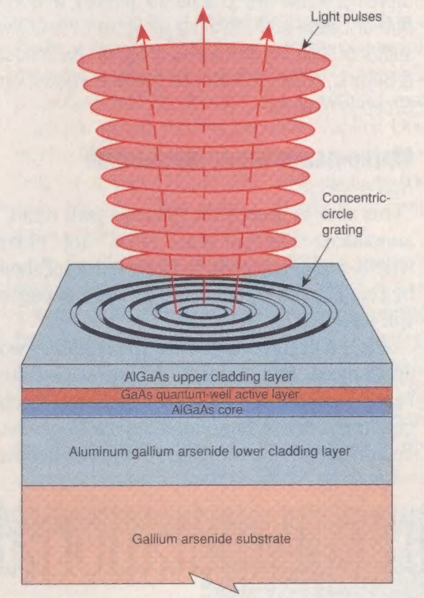
The nonideal shape of the beam of the conventional semiconductor laser is a byproduct of the laser's structure: a long and fairly wide but thin active layer sandwiched between upper and lower cladding layers, with polished mirror-like facets at its two ends repeatedly reflecting photons and causing the active layer to act like a resonant cavity. Each pass through the resonant cavity yields gain. When the laser light emerges from one end of the active layer's rectangular cross section, the beam is naturally elliptical and divergent. This conventional structure is known as an edge-emitting laser.

In the new laser, the optical cavity is two-dimensional instead of one-dimensional. The resonator is defined not by mirrors at opposite ends of a long optical cavity, but by a concentric-circle grating on top of the upper cladding layer [see illustration]. The gratings, with the circles just 0.25 μm apart, are defined on masks by electron-beam lithography, and then transferred to the semiconductor by chemically assisted ion-beam etching.

In the active layer below the grating, light propagates as circular waves outward from the center, rather as the water in a pond ripples outward from the plop of a stone. The circular etchings that define the grating reflect the radially outward-going circular wave to produce a radially inward-going circular wave, and vice versa. With each expansion and contraction, there is gain.

In addition, the new device is a surface-emitting laser instead of an edge-emitting laser: the light shines through the circular grating from a broad area on the top of the structure parallel to the active layer (instead of out of one edge of the active layer). The grating collimates the beam so that it is circular in cross section and has 1/60 the divergence of a traditional edge-emitting laser.

According to Hall, the first prototypes have been optically pumped with the beam of an argon-ion laser focused on the center of the concentric circle grating. Now the group



is working on developing practical techniques of making the gratings more precisely circular with constant line widths, and on ways to pump them electrically, as would be necessary for a commercial device.

A strong see-through magnetic material

A new transparent magnetic material has been developed at Xerox Corp.'s Webster Research Center in Webster, N.Y. Now available as a solid, a water-based liquid, and in film form, its potential applications include color imaging and printing, digital information storage, magnetic refrigeration, leak-free sealing, mechanical-oscillation damping, sensors, and magneto-optical devices.

According to the developer, senior research scientist Ronald F. Ziolo, all the forms of the material are based on crystals of gamma ferric oxide (Fe_2O_3), which have been used for decades as the magnetic coating for audio and video recording tapes. But the crystals take on greater transparency and different magnetic properties in the new material because they are only 2–10 nm across—at least an order of magnitude smaller than the crystals now in use.

To be sure, transparent magnets have been known for years. But in its densest form, each gram of Ziolo's new ferric oxide nanocomposite has a magnetic saturation (the value to which the material can be magnetized in a magnetic field) 15 times greater than that of the next strongest but very transparent material, iron borate. At room temperature, one gram of the new nanocomposite has a magnetic saturation of 50 electromagnet units, or about one-quarter the magnetic saturation of one gram of pure iron.

But at ordinary temperatures this material is not a magnet outside a magnetic field, Ziolo pointed out. That is because the nanocrystals of ferric oxide have magnetic properties different from those of bulk ferric oxide. Because of the nanocrystals' small size, the ferric oxide is no longer ferrimagnetic: that is, the crystals cannot be permanently magnetized. Instead, the nanocrystals have become superparamagnetic, in which state they will be magnetic only in the presence of a magnetic field, adhering strongly to a magnet but not to one another after removal of the magnet.

That superparamagnetic property might be useful in magnetic refrigeration and in the toner for copying machines, Ziolo said.

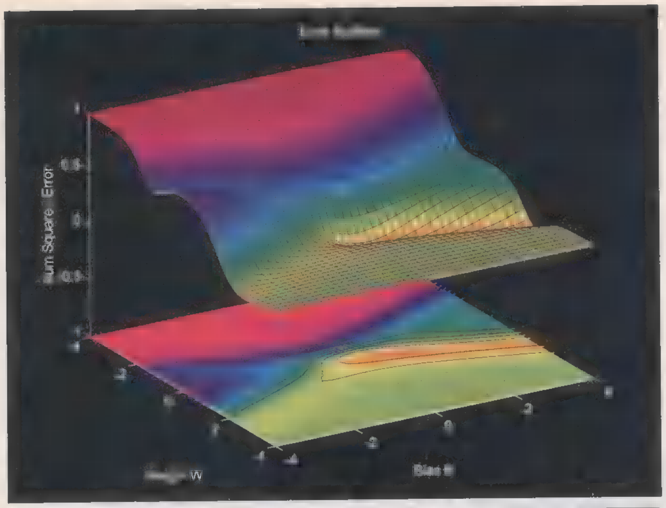
As a ferrofluid, the new nanocomposite has three other possibly valuable properties. First, it appears to have a longer shelf life than other water-based magnetic fluids. Most water-based ferrofluids are unstable and after a few months they degrade or separate. Thus most commercially important ferrofluids are based on hydrocarbons (oil), although the water-based variety is desirable because it may be less harmful to the environment.

Second, although it is not colorless, its amber-red color is lighter than the brown or black of other oil- or water-based ferrofluids, so that it can be dyed to brighter colors. That is likely to be useful in color imaging and printing.

Last, the new ferrofluid is faster to make from the solid form than most others, Ziolo said. The liquid form is made by repeatedly growing gamma ferric oxide nanocrystals within clear beads of a polystyrene resin (often used in water softeners). When enough nanocrystals have grown, the beads are weakened and may be ground up in water to produce the aqueous magnetic fluid. The milling takes a few hours, whereas commercial hydrocarbon-based ferrofluids require months of grinding from much larger solids.

Xerox has made batches of 30–40 kg of the solid form in a pilot plant to verify that the process can be scaled for large quantities.

COORDINATOR: Trudy E. Bell
CONSULTANTS: Ralph H. Baer, Jacob Rabinow



Graphics enhance understanding of neural networks. This surface and contour plot shows how bias and weight affect a backpropagation network's error.

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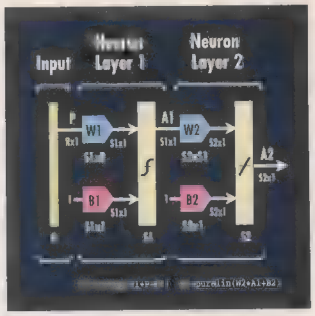

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Parallel, circular beam shines from solid-state laser

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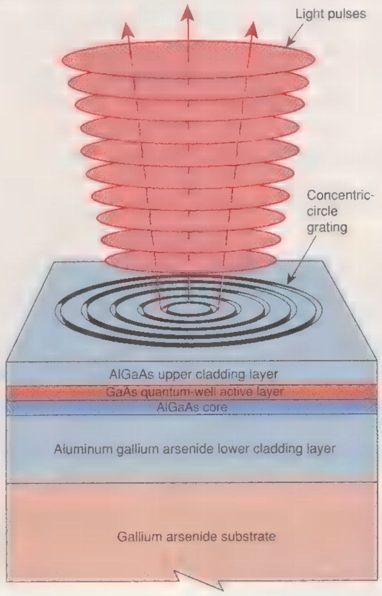

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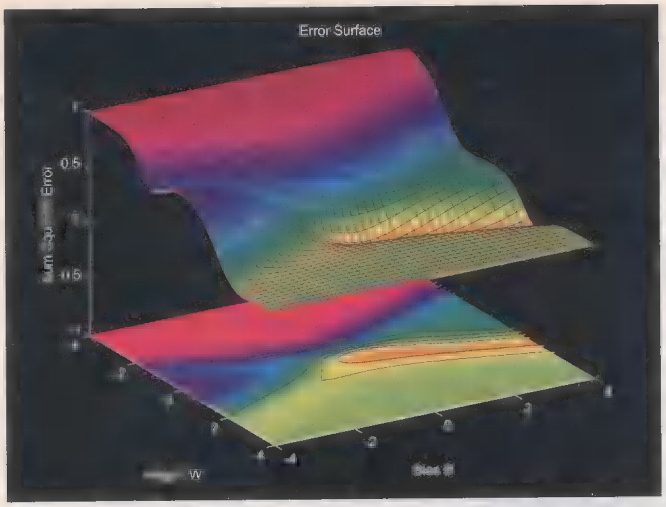

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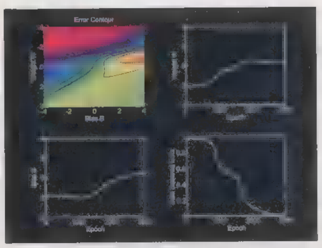

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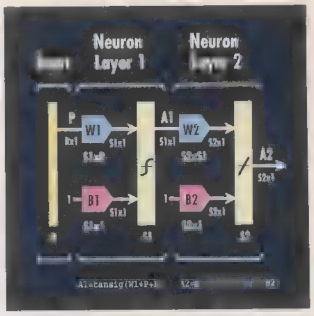

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Circle No. 9

Books

(Continued from p. 7)

claims that Bertrand Russell published his 20 favorite words, including such gems as *inspissated* and *chorasmean.* Not content with that, Pickover chose his own top twenty. No. 1 is *agapemone;* No. 20 is *Yggdrasill.*

Some of Pickover's tales strain credulity. For instance, he claims that in 1975 a Professor Mutcer of Harvard University's electrical engineering department built a machine that would generate "melodies" by activating in random order 88 oscillators, each producing the tone of one of the keys of a piano keyboard. "I urge those of you with access to the necessary analog or digital equipment to attempt such a construction," Pickover writes. "Who knows, maybe it will make you rich."

"Mutcer copyrighted the best of the new musical scores, which were soon bought by large music publishers in New York and Rio de Janeiro. Mutcer was a millionaire." Yes, I see now. It's a joke. Tongue in cheek.

This strange zoo of a book (the author's own description) reminds me of the newspaper feature by Robert Ripley, "Believe it or Not." That, too, was a disturbing mixture of fact and fantasy.

As if the book itself is not enough, the appendices bring more weirdness. Section A.2 is "Product Pavan"—mail-order sources for puzzles, programs, calendars, and other computer-related whatnot. A.3 is "Curiosity Cavalcade": amputated spiders, automated cow-milking, musical scores from gene sequences, the usual.

I suspect that, other than Pickover's first book, nothing quite like this has ever been published. Let's hope no more of it follows.

Reuben Hersh is professor of mathematics at the University of New Mexico in Albuquerque. He is coauthor of Descartes' Dream: The World According to Mathematics *(Harcourt Brace Jovanovich, New York, 1986). He has taught at Stanford University and was a visiting scholar at the Center for Research and Advanced Studies in Mexico City. His research interests center on partial differential equations and related areas in analysis.*

In brief

Prentice Hall's Illustrated Dictionary of Computing. *Nader, Jonar C., Prentice Hall, Englewood Cliffs, N.J., 1992, 526 pp., $24.95.*

Do you read voraciously about computing? Write memos until your co-workers have had it up to here? Are you determined to be the talk of the next computer bowl? Maybe this book can help.

Computing terms, acronyms, and distinguished pioneers and entrepreneurs are all defined or described in clear, concise fashion. Scattered throughout are drawings and photos, many with "gee-whiz" captions: Apple president and former Coca-Cola executive John Sculley invented a type of color television vacuum tube at age 14; Digital Equipment Corp.'s PDP-8/s was the first minicomputer priced under US $10 000 when it was introduced in 1967. Below a photo of Apple's short-lived Lisa computer, however, the author missed an opportunity to mention that the computer was said to have been named after a child fathered by Apple cofounder Steven P. Jobs.

Some of the book's failings can be attributed to the pace of development in the industry. Such recent additions to the lexicon as *palmtop*, *subnotebook*, and *visualization* are all missing. Less easily explained is the absence of the architectural terms *massively parallel* and *very-long instruction word*. Perhaps least excusable is the book's omission of Robert Noyce, the co-inventor of the integrated circuit (only Jack Kilby is honored for the invention).

COORDINATOR: Glenn Zorpette

Recent books

Microprocessor-based Parallel Architecture for Reliable Digital Signal Processing Systems. *George, Alan D.,* and *Hawkes, Lois W.,* CRC Press, Boca Raton, Fla., 1992, 275 pp., US $55.

Handbook of Chemical Vapor Deposition. *Pierson, Hugh O.,* Noyes Publications, Park Ridge, N.J., 1992, 436 pp., $68.

Physics of Nanostructures. Eds. *Davies, J.H.,* and *Long, A.R.,* Institute of Physics Publishing, Bristol, England, 1992, 337 pp., $105.

UNIX in A Nutshell. *Gilly, Daniel, et al.,* O'Reilly & Associates, Sebastopol, Calif., 1992, 444 pp., $9.95.

Phase Conjugate Optics. *Sakai, Jun-ichi,* McGraw-Hill, New York, 1992, 206 pp., $52.

Running Microsoft Excel 4, 3rd edition. *The Cobb Group,* Microsoft Press, Redmond, Wash., 1992, 896 pp., $29.95.

Fuzzy Expert Systems. *Kandel, Abraham,* CRC Press, Boca Raton, Fla., 1992, 316 pp., $59.95.

Algorithmic and Knowledge Based CAD for VLSI. Eds. *Taylor, Gaynor,* and *Russell, Gordon,* Peter Peregrinus, London, England, 1992, 273 pp., $72.

Modern Lens Design: A Resource Manual. *Smith, Warren J.,* McGraw-Hill, New York, 1992, 471 pp., $49.95.

Artificial Intelligence in Engineering Design, Vol. III. Eds. *Tong, Christopher* and *Sriram, Duvvuru,* Academic Press, San Diego, Calif., 1992, 388 pp., $39.95.

First European Conference on Smart Structures and Materials. Eds. *Culshaw, B., et al.,* Institute of Physics Publishing, Bristol, England, 1992, 420 pp., $97.

Combining Information. *National Research Council,* National Academy Press, Washington, D.C., 1992, 217 pp., $28.

Aerials. *Sterba, Kurt N.,* and *Paddle, Lil,* Worldradio, Sacramento, Calif., 1992, 95 pp., $10.

Getting Started with Microsoft Excel 4. *Soucie, Ralph,* Microsoft Press, Redmond, Wash., 1992, 336 pp., $19.95.

Algebraic Computing with Reduce. *MacCallum, Malcolm,* and *Wright, Francis,* Oxford University Press, New York, 1992, 294 pp., $29.95.

Automatic Logic Synthesis Techniques for Digital Systems. *Edwards, M.D.,* McGraw-Hill, New York, 1992, 186 pp., $34.95.

Spicy Circuits. *Chattergy, Rahul,* CRC Press, Boca Raton, Fla., 1992, 241 pp., $39.95.

The Dynamics of Vehicles on Roads and on Tracks. Ed. *Sauvage, Gilles,* Swets & Zeitlinger, Berwyn, Pa., 1992, 692 pp., $116.

Basic Theory of Surface States. *Davison, Sydney G.,* and *Steslicka, Maria,* Oxford University Press, New York, 1992, 223 pp., $65.

In the Image of the Brain. *Jubak, Jim,* Little, Brown & Co., Toronto, Canada, 1992, 348 pp., $24.95.

The Image Processing Handbook. *Russ, John C.,* CRC Press, Boca Raton, Fla., 1992, 445 pp., $89.95.

Artificial Life: The Quest for a New Creation. *Levy, Steven,* Pantheon, New York, 1992, 390 pp., $25.

Time Horizons and Technology Investments. *National Academy of Engineering,* National Academy Press, Washington, D.C., 1992, 108 pp., $19.

Pattern Recognition and Machine Learning. *Anzai, Y.,* Academic Press, San Diego, Calif., 1992, 407 pp., $74.95.

Acoustic Microscopy. *Briggs, Andrew,* Oxford University Press, New York, 1992, 325 pp., $95.

Technically speaking

Playing it safe with sex and gender

Kevin Self

Women form 8.2 percent of the U.S. engineering workforce, according to a 1991 report of the U.S. Bureau of Labor Statistics. Yet, while they are making inroads into positions previously held by men, few would argue that engineering is still a male-dominated profession. Even so, many customs and habits that once seemed innocuous in an all-male workplace now are no longer viewed that way.

Among these, the use of sexist language, either intentionally or unintentionally, is a growing source of anger in the office. One of the thorniest issues for those attempting to counter the habit is the general use of the masculine gender to denote both male and female subjects.

In many Indo-European languages, gender marks words as masculine, feminine, or neuter. This designation is not always accurate, however. Perhaps the most ridiculous example is the German word for girl, *das Mädchen*, which is neuter!

But the English language does not utilize gender. Instead, the sex of a person is designated by using the appropriate pronoun or possesive adjective. Traditionally, *he* has been used to denote a sexless person, making it a neuter pronoun by default. A growing consensus, though, no longer accepts this view, so that the way people communicate is changing.

In *The Elements of Nonsexist Usage* (Prentice Hall Press, 1990), Val Dumond writes that pronouns present one of the greatest challenges for avoiding sexism in language. While *he or she* addresses both sexes, it becomes cumbersome when used more than once or twice.

As a first choice, Dumond suggests omitting the pronoun whenever possible, dodging the problem completely. A sentence such as "An engineer should never trust his computer" can be rewritten as "An engineer should never trust a computer." Alternatively, the plural form may be employed, generating in this case, "Engineers should never trust a computer."

Even traditional correspondence has come under fire. Especially irksome is the use of *Dear Sir(s)* as a universal form of address to an organization, or to an individual when (his? her? their?) sex is not known. Some suggest that the salutatory *Dear* has itself become an archaism, and should be dropped. Letters to organizations, which are usually formal, could use a *To:* line with the name of the organization, department, or title, such as "Customer Service Manager".

If the addressee warrants cordiality, Dumond suggests that a formal salutation or title is superfluous. The simplest solution is to know the title of the addressee and use it in place of the *Dear*. If the sex of the addressee is unknown but the letter writer still insists on the traditional salutation, *Dear Sir or Madam* is acceptable to most people.

The most useful rule is not to imply gender when it is unnecessary to do so. If the sex of the subject is not relevant to the matter, it should be omitted. For dealing with titles and job descriptions, a non–gender- specific form of the word can usually be found. Luckily, two

(Continued on p. 16)

Calendar

Meetings, Conferences, and Conventions

APRIL

International Conference on the Numerical Analysis of Semiconductor Devices and Integrated Circuits—Nasecode (ED); April 13–16; Copper Mountain Resort, Copper Mountain, Colo.; John J.H. Miller, University of Dublin, Trinity College, 39 Trinity College, Dublin 2, Ireland; (353+1) 679 7655; fax, (353+1) 679 2469.

International Magnetics Conference—Intermag (MAG); April 13–16; Folkets Hus, Stockholm, Sweden; John Nyenhuis, 1285 Engineering Building, School of Electrical Engineering, Purdue University, West Lafayette, Ind. 47907-1285; 317-494-3524; fax, 317-494-6440.

International Parallel Processing Symposium—IPPS '93 (C); April 13–16; Newport Beach Marriott Hotel, Newport Beach, Calif.; Ravi Jain, Bellcore, MRE 2P342, 445 South St., Morristown, N.J. 07962; 201-829-2000.

First International Workshop on Systems Management (C); April 14–16; Faculty Center, University of California, Los Angeles; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C., 20036; 202-371-1013; fax, 202-728-0884.

Third International Symposium on Integrated Network Management (COM); April 17–23; Sheraton Palace Hotel, San Francisco; Michele Nessier, Action Motivation, 118 King St., Room 315, San Francisco, Calif. 94107; 415-512-0800.

International Workshop on Research Issues in Data Engineering: Interoperability in Multi-Database Systems (C); April 18–20; Penta Hotel, Vienna, Austria; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Conference on Indium Phosphide and Related Materials (ED); April 18–22; Maison de la Chimie, Paris, France; Susan Evans, IEEE/LEOS, 445 Hoes Lane, Piscataway, N.J. 08855-1331; 908-562-3896; fax, 908-562-1571.

IEEE/IEEJ Joint IAS Power Conversion Conference: Yokohama—PCC (IA, PEL, et al.); April 19–21; Pacifico Yokohama, Yokohama, Japan; Atsuo Kawamura, Department of Electricity and Computer Engineering, Yokohama National University, Hodogayo-ku, Yokohama, 240 Japan; (81+45) 335 1451, ext. 2834; fax, (81+45) 338 1157.

National Radar Conference (AES, Boston Section); April 19–22; Colonial Hilton Inn and Resort, Wakefield, Mass.; William Donnellan, Westinghouse Corp., 275 Wyman St., Waltham, Mass. 02154; 617-890-9370; fax, 617-890-1206.

Ninth International Conference on Data Engineering (C); April 19–23; Penta Hotel, Vienna, Austria; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-782-0884.

Third European Test Conference (C); April 19–24; World Trade Center, Rotterdam, the Netherlands; Jacques Kevers, ETC '93 Secretariat, IEEE Computer Society, 13 Avenue de l'Aquilon, B-1200 Brussels, Belgium; (32+2) 770 2242; fax, (32+2) 770 8505.

Second Workshop on Enabling Technologies for Concurrent Engineering: Infrastructure for Concurrent Engineering (C); April 20–22; West Virginia University, Morgantown; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013.

Rural Electric Power Conference (IA); April 25–27; Allis Plaza Hotel, Kansas City, Mo.; LaVerne E. Stetson, USDA Agricultural Research, 252 Chase Hall, UNL, Lincoln, Neb. 68583-0934; 402-472-2945; fax, 402-472-6338.

IEEE members attend more than 5000 IEEE professional meetings, conferences, and conventions held throughout the world each year. For more information on any meeting in this guide, write or call the listed meeting contact. Information is also available from: Conference Services Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 80055; 908-562-3878; submit conferences for listing to: Ramona Foster, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017; 212-705-7305.

For additional information on hotels, conference centers, and travel services, see the Reader Service Card.

Technically speaking

(Continued from p. 13)

of the most common terms in engineering, *engineer* and *technician*, are already grammatically neuter.

Dumond and others note that a number of grammatical purists insist that the masculine form is and has been acceptable as a gender neutral term, and overhauling the English language would tarnish some of its beauty. Whichever viewpoint is held, the changing political and business climate demands an increasing awareness of the sensitivities of fellow workers. When it comes to dealing with sex in written and spoken communications, play it safe.

Name games

As mentioned in the January issue of *IEEE Spectrum*, Intel Corp., Santa Clara, Calif., has finally decided on a name for its fifth- generation microprocessor. For some time there has been speculation that the successor to the Intel 486, known semi-publicly by its internal project designation P5, might not follow the x86 naming convention. But the assumption that the newest member of the 8086-compatible series would become the Intel 586 was thrown into doubt after unsuccessful attempts to trademark the names of the company's 80386- and 80486-compatible processors.

As expected, therefore, the trademarked Pentium microprocessor has broken with tradition. Seeking to protect both the reputation of the products in the x86 family and their market share, Intel decided to choose a name that was unique and could be trademarked.

After an extensive search involving several advertising agencies and in-house naming contests, Intel chose Pentium. The word retains the idea of a fifth generation by incorporating a form of the Greek word for five, *pente*, although with the Latin ending, *-ium*.

Intel has decreed that the Pentium name is actually an adjective and must be followed by a noun. For example, "Buy Pentium microprocessors" would be correct, but "Buy Pentiums for your computer" would be incorrect. In general, there is no steadfast rule as to whether processor names are nouns or adjectives, but when in doubt, use them as adjectives.

Caffeinated cooperation

Business breeds strange bedfellows, to be sure. To highlight new products of interest to their readers, trade magazines often sponsor awards that the product's manufacturer may subsequently use in its advertising. Sometimes these awards are cosponsored by third parties, eager for advertising. The resulting combination of products and sponsors can make for what seems, at first, an unlikely alliance.

One such advertisement touted the fact that the software it was promoting had won *Computer Language* magazine's Product Excellence Award. The award had a cosponsor, however, who caught Technically Speaking's eye. It was Jolt Cola, well-known to college students as the drink of choice for all-night study sessions. The stimulating substance boasts twice the caffeine of most cola soft drinks, and forsakes corn syrup or artificial sweeteners for natural cane sugar. The effects of the resulting sugar and caffeine rush are the stuff of collegiate legend, and convenience stores near college campuses stock up with Jolt Cola as final exams approach.

In the words of the magazine, "Jolt is the Gatorade of programming, the canonical beverage of all-night hack attacks. It's associated, in our minds, with all that's best about programming: intense concentrated effort illuminated by flashes of insight. Even Jolt's lightning-bolt logo was appropriate for the tone of the award." The two parties saw a natural partnership, and the rest is history.

Contributing Editor Kevin Self (M) surveys the etymological world from his workstation at Texas Microsystems Inc., in Houston, Texas.

CONSULTANT: Anne Eisenberg, Polytechnic University

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…irement Science and …*n, P.H., et al.,* John …York, 1992, 327 pp.,

Advances in Computers, Vol. 34. Ed. *Yovits, Marshall C.*, Academic Press, San Diego, Calif., 1992, 422 pp., $79.95.

Engineering The Human-Computer Interface. Ed. *Downton, Andy,* McGraw-Hill, New York, 1992, 423 pp., $58.95.

The X Window System Server. *Israel, Elias,* and *Fortune, Erik,* Digital Press, Burlington, Mass., 1992, 534 pp., $45.95.

High Level Synthesis of ASICs Under Timing and Synchronization Constraints. *Ku, David*

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Recent books

(Continued from p. 12)

Intelligent Robotic Systems: Theory, Design and Applications. *Valavanis, Kimon P.*, and *Saridis, George N.*, Kluwer Academic, Dordrecht, the Netherlands, 1992, 300 pp., $67.50.

Linear Systems Theory. *Szidarovszky, Ferenc*, and *Bahill, A. Terry*, CRC Press, Boca Raton, Fla., 1992, 425 pp., $59.95.

The SECD Microprocessor: A Verification Case Study. *Graham, Brian T.*, Kluwer Academic, Dordrecht, the Netherlands, 1992, 176 pp., $62.50.

Statistical Methods for Testing, Development, and Manufacturing. *Breyfogle, Forrest W., III*, John Wiley & Sons, New York, 1992, 516 pp., $64.95.

The Windows Interface. *Microsoft Corporation*, Microsoft Press, Redmond, Wash., 1992, 2140 pp., $24.95.

Computer Communications Networks. *Waters, Gill*, McGraw-Hill, New York, 1992, 375 pp., $50.95.

Acousto-Optic Devices. *Xu, Jieping*, and *Stroud, Robert*, John Wiley & Sons, New York, 1992, 652 pp., $69.95.

Anatomy of a Silicon Compiler. Ed. *Brodersen, Robert W.*, Kluwer Academic, Dordrecht, the Netherlands, 1992, 362 pp., $90.

The Spectroscopy of Semiconductors. Eds. *Seiler, David G.*, and *Littler, Christopher L.*, Academic Press, San Diego, Calif., 1992, 427 pp., $99.50.

Microsoft Excel Macros, Version 4. *Wexler, Steve*, and *Sharer, Julianne*, Microsoft Press, Redmond, Wash., 1992, 292 pp., $34.95.

Personal & Mobile Radio Systems. Ed. *Macario, R.C.V.*, Peter Peregrinus, London, 1992, 328 pp., $35.

HF Communications: Science and Technology. *Goodman, John M.*, Van Nostrand Reinhold, New York, 1992, 632 pp., $74.95.

U.S.-Japan Technology Linkages in Biotechnology. *National Research Council*, National Academy Press, Washington, D.C., 1992, 98 pp., $19.

Fuzzy, Holographic, and Parallel Intelligence. *Soucek, Branko*, and *The IRIS Group*, John Wiley & Sons, New York, 1992, 350 pp., $54.95.

Image Processing. Ed. *Pearson, Don*, McGraw-Hill, New York, 1992, 314 pp., $58.95.

Nonlinear Vision: Determination of Neural Receptive Fields, Function, and Networks. *Pinter, Robert B.*, and *Nabet, Bahram*, CRC Press, Boca Raton, Fla., 1992, 549 pp., $79.95.

Introduction to Measurement Science and Engineering. *Sydenham, P.H., et al.*, John Wiley & Sons, New York, 1992, 327 pp., $39.95.

Advances in Computers, Vol. 34. Ed. *Yovits, Marshall C.*, Academic Press, San Diego, Calif., 1992, 422 pp., $79.95.

Engineering The Human-Computer Interface. Ed. *Downton, Andy*, McGraw-Hill, New York, 1992, 423 pp., $58.95.

The X Window System Server. *Israel, Elias*, and *Fortune, Erik*, Digital Press, Burlington, Mass., 1992, 534 pp., $45.95.

High Level Synthesis of ASICs Under Timing and Synchronization Constraints. *Ku, David*

Recent books

C., and *De Micheli, Giovanni*, Kluwer Academic, Dordrecht, the Netherlands, 1992, 300 pp., $90.

Introductory C Pointers, Functions, and Files. *Petersen, Richard*, Academic Press, San Diego, Calif., 1992, 595 pp., $34.95.

Fast Learning and Invariant Object Recognition. *Soucek, Branko*, and *The IRIS Group*, John Wiley & Sons, New York, 1992, 279 pp., $49.95.

Hybrid Architectures for Intelligent Systems. *Kandel, Abraham*, and *Langholz, Gideon*, CRC Press, Boca Raton, Fla., 1992, 420 pp., $89.95.

C+C++ Programming with Objects in C and C++. *Holub, Allen I.*, McGraw-Hill, New York, 1992, 300 pp., $24.95.

Directed Sonar Sensing for Mobile Robot Navigation. *Leonard, John J.*, and *Durrant-Whyte, Hugh F.*, Kluwer Academic, Dordrecht, the Netherlands, 1992, 183 pp., $72.50.

Changing Our Ways: America and the New World. Carnegie Endowment National Commission, Washington, D.C., 1992, 90 pp., $9.95.

Inorganic Chemistry. *Sharpe, A.G.*, John Wiley & Sons, New York, 1992, 300 pp., $44.95.

Visual Basic—Game Programming for Windows. *Young, Michael J.*, Microsoft Press, Redmond, Wash., 1992, 514 pp., $39.95.

Modern Digital Design and Switching Theory. *Fabricius, Eugene D.*, CRC Press, Boca Raton, Fla., 1992, 470 pp., $55.

Reliability Evaluation of Engineering Systems, 2nd edition. *Billinton, Roy*, and *Allan, Ronald N.*, Plenum Press, New York, 1992, 453 pp., $59.50.

Science and Technical Writing. *Rubens, Philip*, Henry Holt, New York, 1992, 513 pp., $39.95.

Progress in Computer Graphics, Vol. 1. Eds. *Zobrist, George W.*, and *Sabharwal, Chaman*, Ablex Publishing, Norwood, N.J., 1992, 336 pp., $69.50.

MVS Performance Management. *Samson, Stephen L.*, McGraw-Hill, New York, 1992, 385 pp., $44.95.

Microwave and Optical Transmission. *Olver, A. David*, John Wiley & Sons, New York, 1992, 389 pp., $69.95.

Engineering Your Start-Up. *Baird, Michael L.*, Professional Publications, Belmont, Calif., 1992, 284 pp., $19.95.

Numerical Techniques in Electromagnetics. *Sadiku, Matthew N.O.*, CRC Press, Boca Raton, Fla., 1992, 690 pp., $65.

Artificial Intelligence in Engineering Design, Vol. II. *Tong, Christopher*, and *Sriram, Duvvuru*, Kluwer Academic, Dordrecht, the Netherlands, 1992, 524 pp., $39.95.

Microsoft Word for Windows 2.0 Macros. *Borland, Russell*, Microsoft Press, Redmond, Wash., 1992, 471 pp., $34.95.

Cool Energy. *Brower, Michael*, MIT Press, Cambridge, Mass., 1992, 219 pp., $12.95.

Strategies for Innovation. *Rouse, William B.*, John Wiley & Sons, New York, 1992, 249 pp., $49.95.

A Guide to VHDL. *Mazor, Stanley*, and *Langstraat, Patricia*, Kluwer Academic, Dordrecht, the Netherlands, 1992, 350 pp., $75.

Calendar

(Continued from p. 14)

IFIP Symposium on Hardware Description Languages (C); April 25–28; Chateau Laurier Hotel, Ottawa, Canada; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Second Annual Symposium on Document Analysis and Information Retrieval (C); April 26–28; Caesars Palace Hotel, Las Vegas, Nev.; William L. Brogan, University of Nevada, 4505 Maryland Parkway, Las Vegas, Nev. 89154-4026; 702-597-4183.

Technical Conference on Rubber and Plastics Industry (IA, Akron Section); April 26–28; Quaker Square Hilton, Akron, Ohio; Joel A. Rosenbaum, 1501 Raff Rd., S.W., Box 80777, Canton, Ohio 44710; 216-478-6100; fax, 216-478-8477.

12th Symposium on Mass Storage Systems (C); April 26–29; Monterey Marriott, Monterey, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W.; Washington, D.C. 20036-1903; 202-371-1013.

Electro '93 (Region 1 et al.); April 27–29; Raritan Center, Edison, N.J.; Joan Carlisle, ECM, 8110 Airport Blvd., Los Angeles, Calif. 90045-3194; 800-877-2668, ext. 250, or 310-215-3976; fax, 310-641-5117.

International Conference on Acoustics, Speech and Signal Processing (SP); April 27–30; Minneapolis Convention Center, Minnesota; Mostafa Kaveh, Department of Electrical Engineering, University of Minnesota, 200 Union St., S.E., Minneapolis, Minn. 55455; 612-625-0720.

MAY

International Symposium on Circuits and Systems—IS CAS '93 (CAS); May 2–6; Sheraton Chicago Hotel and Towers, Chicago; W. Kenneth Jenkins, Coordinated Science Laboratory, University of Illinois, 1101 W. Springfield Ave., Urbana, Ill. 61801; 217-333-2510; fax, 217-244-1764.

Conference on Lasers and Electro-optics/Quantum Electronics Lasers Science (LEO); May 2–7; Baltimore Convention Center, Maryland; Barbara Hicks, OSA, 2010 Massachusetts Ave., N.W., Washington, D.C. 20036; 202-371-1013.

Industrial and Commercial Power Systems Annual Technical Conference (IA); May 3–6; St. Petersburg Hilton, St. Petersburg, Fla.; James H. Beall, 9836 Stephenson Dr., New Port Richey, Fla. 34655; 813-376-2790.

Annual Textile, Fiber and Film Industry Technical Conference (IA); May 4–6; Crowne Plaza Ravinia, Atlanta, Ga.; Robert G. Henderson , 4049 Santeelau Trail, Stone Mountain, Ga. 30083; 404-294-6989.

Power Industry Computer Applications Conference (PE); May 4–7; Registry Resort and Scottsdale Plaza Resort, Scottsdale, Ariz.; Matt Tani, Arizona Public Service Co., Box 53999, Mail Station 2387, Phoenix, Ariz. 85072-3999; 602-250-1055; fax, 602-250-1050.

Custom Integrated Circuits Conference (ED); May 9–12; Town and Country Hotel, San Diego, Calif.; Roberta Kaspar, 1597 Ridge Rd. West, Suite 101C, Rochester, N.Y. 14615; 716-865-7164; fax, 716-865-2639.

International Symposium on Electronics and the Environment (TAB);

Calendar

May 10–12; Hyatt Regency Crystal City, Arlington, Va.; Conference Registrar, IEEE Technical Activities, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3878; fax, 908-562-1571.

Photovoltaic Specialists Conference (ED); May 10–14; Galt House, Louisville, Ky.; Eldon C. Boes, National Renewable Energy Laboratory, Suite 710, 409 12th St., S.W., Washington, D.C. 20024; 202-484-1090; fax, 202-484-8177.

15th Annual Electronics Exposition and Symposium (Albuquerque Section); May 11–13; Albuquerque Convention Center, New Mexico; Meridee Katz, ISE Exposition Manager, 8100 Mountain Rd., N.E. #109, Albuquerque, N.M. 87110-7827; 505-262-1023.

Fourth International Conference on Computer Vision (C); May 11–14; Humboldt Universität, Berlin, Germany; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Symposium on VLSI Technology Systems and Applications (ED); May 12–14; Lai Lai Sheraton, Taipei, Taiwan; Genda J. Hu, Cypress Semiconductor, MS/1-1, 3901 N. First St., San Jose, Calif. 95134; 408-943-4861; fax, 408-943-2118.

Workshop on Real-Time Applications (C): May 13; Hotel Ramada, New York City; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Workshop on VLSI Process and Device Modeling—VPAD (ED); May 14–15; New Public Hall, Nara, Japan; Masao Fukuma, Microelectronics Research Laboratories, NEC Corp., 1120 Shimokuzawa, Sagamihara, Kanagawa 229, Japan; (81+42) 771 0798; fax, (81+42) 771 0886.

20th International Symposium on Computer Architecture (C); May 16–19; Sheraton Harbour Island Hotel, San Diego, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Wescanex '93—Conference on Communications, Computers and Power in the Modern Environment (Region 7 et al.); May 17–18; University of Sas-

Calendar

katchewan, Saskatoon, Canada; Ron Fleming, Department of Electrical Engineering, University of Saskatchewan, Saskatoon, Sask. S7N OWO, Canada; 306-966-5299 or 5379; fax, 306-966-8710.

VLSI Technology Symposium (ED); May 17–19; Kyoto Grand Hotel, Kyoto, Japan; James T. Clemens, AT&T Bell Laboratories, 600 Mountain Ave., Murray Hill, N.J. 07974; 908-582-2800; fax, 908-582-2793.

Particle Accelerator Conference (NPS); May 17–20; Omni Shoreham, Washington, D.C.; Christoph W. Leemann, CEBAF, 12000 Jefferson Ave., Newport News, Va. 23606; 804-249-7554.

Eighth Annual Conference on Structure in Complexity Theory (C); May 17–21; Sheraton Harbor Island Hotel, San Diego, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

15th International Conference on Software Engineering (C, ACM); May 17–21; Stouffer Harbor Place Hotel, Baltimore, Md.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 201-728-0884.

Instrumentation and Measurement Technology Conference (IM); May 18–20; Hyatt Regency Hotel, Irvine, Calif.; Robert Myers, 3685 Motor Ave., Suite 240, Los Angeles, Calif. 90034; 310-287-1463; fax, 310-287-1851.

International Symposium on Power Semiconductor Devices and ICs (ED); May 18–20; Hyatt Regency Monterey, Monterey, Calif.; M. Ayman Shibib, AT&T Bell Laboratories, Box 13566, Reading, Pa. 19612-3566; 215-939-6576; fax, 215-939-6795.

University/Government/Industry Microelectronics Symposium (ED); May 18–20; North Carolina State University, Raleigh; Jeffrey A. Coriale, North Carolina State University, Box 7920, Centennial Campus, Raleigh, N.C. 27695; 919-515-5053; fax, 919-515-5055.

Vehicular Technology Conference—VTC (VT, North Jersey Section); May 18–20; Meadowlands Hilton Hotel, Secaucus, N.J.; George D. Graul, 9C Alabama Court, Cheesequake Village, Matawan, N.J. 07747; 908-290-1128; fax, 908-290-1932.

Symposium on Solid Modeling and Applications (C); May 19–21; Ramada Renaissance, Montreal; IEEE Computer Society, Conference Department, 1730 Massachusetts Avenue, N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Symposium on VLSI Circuits (SSC); May 19–21; Kyoto Grand Hotel, Kyoto, Japan; Dru Montgomery, Courtesy Associates, 655 15th St., N. W. #300, Washington, D.C. 20005; 202-347-5900; fax, 202-347-6109.

Pacific Rim Conference on Communications Computers and Signal Processing (Region 7 et al.); May 20–21; Victoria Conference Centre, Victoria, B.C., Canada; Russ Williams, Conference Services, University of Victoria, Box 3030, Victoria, BC V8W 3N6, Canada; 604-721-8451; fax, 604-721-8774.

International Software Metrics Symposium (C); May 21–22; Stouffer Hotel, Baltimore, Md.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington,

D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Conference on Communications (COM); May 23–26; CICG Centre International de Conférences de Genève, Geneva, Switzerland; Peter Leuthold, Institut für Kommunikationstechnik, ETH-Zentrum, CH-8092 Zurich, Switzerland; (41+1) 256 2788; fax, (41+1) 262 0943.

Workshop on Interconnections Within High Speed Digital Systems (E, COM, LEO); May 23–26; Eldorado Hotel, Santa Fe, N.M.; Cathy Goldsmith, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3894; fax, 908-562-1571.

35th Cement Industry Technical Conference (IA); May 23–27; Royal York Hotel, Toronto; John MacRitchie, Leeds & Northrup Canada, 1344 Fewster Dr., Mississauga, Ont., Canada L4W 1A4; 416-238-6850.

Third Annual Dual-Use Technologies and Applications Conference (MV Section); May 24–27; Suny Institute of Technology, Utica/Rome, N.Y.; John Salerno, c/o College Relations Office, Suny Institute of Technology, Box 3050, Utica/Rome, N.Y. 13504-3050; 315-792-7114; fax, 315-792-7222.

23rd International Symposium on Multiple Valued Logic (C); May 24–27; Hyatt Regency Hotel, Sacramento, Calif.; K.W. Current, ECE Department, University of California, Davis, Calif. 95616; 916-752-0583; fax, 916-752-8428.

National Aerospace and Electronics Conference (AES, Dayton Section); May 24–28; Dayton Convention Center, Dayton, Ohio; Sue Murphy, ASC/ENES, Wright-Patterson AFB, Ohio 45433-6503; 513-255-6281.

Regional Conference on Aerospace Control Systems (CS); May 25–27; Rockwell Science Center, Thousand Oaks, Calif.; Ching-Fang Lin, American GNC Corp., 9131 Mason Ave., Chatsworth, Calif. 91311; 818-407-0092.

International Conference on Distributed Computing Systems—ICDCS '93 (C); May 25–28; Pittsburgh Hilton and Towers, Pittsburgh; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Canadian Workshop on Information Theory (IT, Region 7); May 30–June 2; Le Riviera Conference Centre, Rockland, Ont.; T. Aaron Gulliver, Department of Systems and Computer Engineering, Carleton University, Ottawa, Ont., Canada K1S 5B6; 613-788-5734; fax, 613-788-5727.

JUNE

43rd Electronic Components and Technology Conference—ECTC '93 (CHMT); June 1–3; Buena Vista Palace Hotel, Orlando, Fla.; James A. Bruorton, Kemet Electronics, Box 5928, Greenville, S.C. 29606; 803-963-6621

International Symposium on Industrial Electronics—ISIE '93 (IA et al.); June 1–3; Hotel Agro, Budapest, Hungary; Okyay Kaynak, Bogazici University, Bebek, 80815 Istanbul, Turkey; (90+1) 265 9909; fax, (90+1) 257 5030.

International Symposium on Electron, Ion and Photon Beams (ED); June 1–4; Sheraton Harbor Island, San

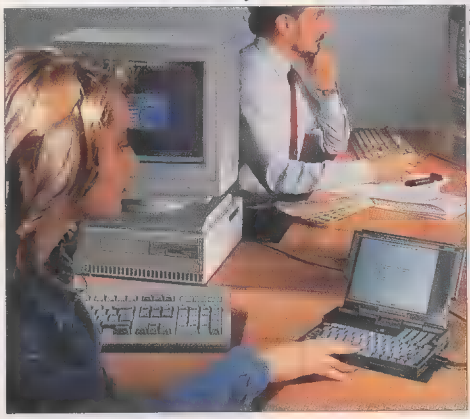
(Continued on p. 68E)

EEs' tools & toys

An economical subnotebook computer that talks

Olivetti's new Quaderno is a subnotebook computer with a difference—a built-in facility for recording audio directly on the machine's 20M-byte hard disk. In addition, the Quaderno (Italian for "notebook") has 1M-byte of RAM, all of which is usable because the MS-DOS 5.0 operating system is stored elsewhere on ROM.

Weighing in at a mere kilogram with its nickel cadmium battery in place, the Quaderno fits an A5 form factor—210 by 148 by 25 mm. Its central processor is a 16-MHz NEC V30HL, an 8086-compatible chip specially designed for low-power, mobile computing. The computer has a slot for PC Memory Card International Association (PCMCIA) memory cards; an external floppy-disk drive is optional. The Quaderno lists for US $1200.



Ing. C. Olivetti & Co. SpA

The Quaderno subnotebook computer from Olivetti has built-in facilities for the voice annotation of its files. At maximum compression, it can squeeze 10 minutes of speech into a megabyte of disk space.

In its recording mode, audio captured with the built-in or an external microphone can be stored as separately identified messages or linked to specific locations in a text file—a word or sentence, for example. Up to eight separate comments can be recorded and linked to text. At places in the document selected by the user, a "voice annotation" icon indicates a related verbal comment, which may be played back by moving the cursor to the icon and selecting a command from the menu. Two data compression rates are available, or no compression at all; at highest compression, 10 minutes of audio recording will occupy a megabyte of memory.

Of course, what you say to your friends and colleagues when they see you talking to your subnotebook is up to you. *Contact: Olivetti Office U.S.A., 765 U.S. Highway 202, Bridgewater, N.J. 08807; 908-526-8200; fax, 908-526-8405; (in Europe) Ing. C. Olivetti & Co. SpA., Via Jervis 77 10015 Ivrea, Turin, Italy; (39+11) 0125 52 26 39; or* **circle 100.**

PERIPHERALS

Recordable-CD drive

Write-once/read-many-times (WORM) optical-disc drives are great—they allow users to record, as well as play back, huge amounts of data. But until now, they have not been compatible with standard CD-ROM players, and therefore users of the most popular optical storage medium could not get the benefits of incremental writing—filling a disk partially on one occasion and then adding data later on.

Now, thanks to Ricoh and its RS-9200CD recordable compact-disc (CD) drive, that situation has changed. The new drive has a recording and transfer rate of 150 kB/s and an average access time of less than 500 ms. Its recording capacity is 650 MB.

The drive is a compact desktop unit measuring about 210 by 310 by 130 mm and weighing about 6.5 kg. It carries a price tag of US $4165.

Discs recorded on the RS-9200CD can be played on any conventional CD player. *Contact: Ricoh Corp., 5 Dedrick Pl., West Caldwell, N.J. 07006; 201-882-2000; fax, 201-882-2506; or* **circle 101.**

Inexpensive control

In an effort to cut the cost and improve the reliability of computer communications with RS-232 peripherals, Gigatec SA of Switzerland has developed the LISBUS Asynchronous I/O system, which daisy-chains more than 100 peripherals at distances of up to 1.4 km through a single PC communications port. LISBUS, which stands for linear sequential bus, uses a sequential scheme to select peripherals one at a time and communicate with them. The transmission parameters may be different for each peripheral, if desired.

Two major features of LISBUS are its small size and low cost. The hardware at each peripheral and at the host computer is contained in the RS-232 connector at each location. The price for a starter pack is US $995, which buys one bus interface processor (for connecting to the computer), one bus terminator module (for the last peripheral on the daisy chain), three I/O modules (for the other peripherals), software, a 6-meter cable, a power supply, and manuals. Extra I/O modules are $130 each.

Software development tools for creating custom applications cost a further $280.

Tools & toys

Contact: Gigatec (USA) Inc., Box 4705, Portsmouth, N.H. 03802-4705; 603-433-2227; fax, 603-433-5552; (in Europe) Gigatec SA, Ch. des Plans-Praz, 1337 Vallorbe, Switzerland; (41+21) 843 37 36; fax, (41+21) 843 33 25; or **circle 101.**

EDUCATION

Complying with the EC's EMC directive

In 1992, the European Community (EC) issued a comprehensive directive on electromagnetic compatibility (EMC) covering just about all electrical and electronics products that are capable of producing emissions or are susceptible to them. The document goes into effect on Jan. 1, 1996, and will apply to all European imports regardless of where they are manufactured. After that date, failure to comply with the directive will be a criminal offense in the countries in the Community.

To help manufacturers in the United Kingdom learn about complying with the directive, the British government's Department of Trade and Industry has sponsored a set of three videotapes entitled "EMC—The Competitive Edge." The first tape, "The Competitive Edge," is aimed more at senior management than at technical personnel; it gives insight into EMC from a layman's point of view, and shows how the regulations can be used to gain competitive advantage.

"The Designer's Guide," the second tape, discusses means for achieving electromagnetic compatibility—the use of filters and shielding, for example. It is aimed mainly at designers who have not given much previous thought to EMC. The third tape, "The Routes to Compliance," describes ways of demonstrating compliance. Even experienced EMC engineers can learn something from this tape, which is specific to the EC directive.

The set of three tapes is priced at £175 in the UK and $399 in the United States. *Contact: Technology International Inc., 705 Twin Ridge Lane, Richmond, Va. 23235; 804-560-5334; fax, 804-560-5342; (in the UK), Technical Video Sales, Franks Hall, Horton Kirby, Kent DA4 9BR, England; (44+322) 222 222; fax, (44+322) 289 953; or* **circle 103.**

GENERAL INTEREST

Historical sights for EEs

Attendees at the Electro '93 show at the end of this month may be interested in visiting some New York City locales of special historical significance to electrical and electronics engineering—the site of Edison's first power plant, the old Bell Laboratories building, and

Mike Riezenman

This plaque at 40 Fulton Street (near the corner of Pearl Street) in New York City commemorates the first electric power plant in the United States.

Major Edwin Howard Armstrong's last home, to name just a few.

At least that is the hope of Signature Tours, which specializes in the design of custom itineraries in the New York City area. The company has put together the core of what it calls a Techie Tour of New York, and is prepared to flesh out that core in accordance with a client's specifications.

Signature offers both escorted tours and blueprints for self-guided exploration. *Contact: Signature Tours, 520 East 76 St., New York, N.Y. 10021; 212-517-4306; fax, 724-1278; or* **circle 105.**

SOFTWARE

Shareware bonanza

If you are a computer enthusiast of the type who feels that the more software you have, the better off you are, Crosley Software's shareware bonanza should set your disc spinning. The company is offering a collection of more than 20 000 shareware programs on three CD ROMs for US $69. In uncompressed form, the programs amount to more than 3 GB of data, which works out to less than 3 cents per megabyte.

The programs are stored on the CD-ROM discs in compressed form, so a decompression utility is included in the package. So is a Program Lister, which simplifies the search for programs by listing them in categories and subcategories.

The software collection covers games, pictures (along with a viewing program), languages, education, business, communications, and ham radio. More than 2000 of the titles are Windows applications.

Volume discounts are available, starting with as few as two sets (which cuts the price to US $51 per set). *Contact: Crosley Software, Box 276, Alburg, Vt. 05440; 514-739-9328; fax, 514-345-8303; or* **circle 104.**

STANDARDS

Choosing from 1000 standards

Need a Joint Electron Device Engineering Council (Jedec) drawing? How about a Tube Engineering Advisory Panel standard or a document from the Telecommunications Industry Association (TIA) or a similar Electronic Industries Association (EIA) publication? Chances are it is in the new 120-page catalog recently put out by the EIA.

The catalog boasts over a thousand items,

including joint standards developed in collaboration with other organizations. It is available free of charge. *Contact: Global Engineering Documents, Box 19539, Irvine, Calif. 92713-9539; toll-free, 800-854-7179; or 714-261-1455; fax, 714-261-7892; or* **circle 106.**

INSTRUMENTATION

Eliminating alias errors

Aliasing errors arise in sampled-data systems when the input signal is sampled too slowly—at under twice the frequency of the highest-frequency component of the input signal. They typically occur when the input signal contains higher frequencies than the system designer expected. They can therefore be eliminated by passing the signal through a low-pass filter before sampling it.

But how should the filter be specified? And what effect will it have on the signal? These and other questions are addressed in a series of five application notes from Alligator Technologies. The notes talk mostly about Alligator's AAF-1 anti-alias filter board, but they cover general principles as well.

The application notes, Nos. AP-301 through AP-305, are free. *Contact: Alligator Technologies, Box 9706, Fountain Valley, Calif. 92728-9706; 714-850-9984; fax, 714-850-9987; or* **circle 107.**

Pulsed EMI testing pitfalls

Testing electronic equipment for susceptibility to pulsed electromagnetic interference like electrostatic discharge (ESD) and electrical fast transients (EFT) is fraught with pitfalls. Some ESD testers may lose part of their charge as they approach the unit under test, for example, leading the unsuspecting test engineer to think that he or she has performed a more rigorous test than was actually carried out. Similarly, some EFT simulators may produce substandard outputs when called upon to work into certain impedances.

These and other issues are covered in an eight-page application note, No. AN-311, which is available free of charge from KeyTek. *Contact: KeyTek Instrument Corp., 260 Fordham Rd., Wilmington, Mass. 01887; 508-658-0880; fax, 508-657-4803; or* **circle 108.**

MEDICAL

Fighting carpal tunnel syndrome

Repetitive motion of the hands is a major cause of workplace injuries like carpal tunnel syndrome. People who spend hours on end at a keyboard are most affected, but assemblers and others also suffer. To combat those injuries, the Northeast Orthopedic Appliance Group has developed the Alpha Glove, a fingerless gauntlet that massages the wrist and supports it much as a wrist splint does.

The gloves are being sold through a network of distributors set up by the Samson Marketing Group. Prices vary, but are in the range of US $15 to $19 a pair.

Samson Marketing Group

By supporting and massaging the hand, the fingerless Alpha Glove helps prevent such injuries due to repetitive motion as carpal tunnel syndrome.

Both customer and distributor inquiries are invited. *Contact: Samson Marketing Group, 74 Dexter St., Providence, R.I. 02909; 401-272-4400; toll-free, 800-727-1712; or* **circle 109.**

COMPONENTS

Arrays of relays on display

Almost 1800 stock relays are included in Catalog 13C222 from Potter & Brumfield. Among them are electromechanical, solid-state, and time-delay devices. Also listed in the 40-page document are input/output modules, circuit breakers, sensors, sockets, mounting boards, and accessories.

A photograph and brief set of specifications are given for each product series. There is no charge for the catalog. *Contact: Potter & Brumfield Inc., 200 South Richland Creek Dr., Princeton, Ind. 47671; 812-386-1000; or* **circle 110.**

DIGITAL SIGNAL PROCESSING

Fast routines

When speed is important (and when is it not?) there is much to be said for coding at least the most frequently used parts of programs in assembly language. Although doing so definitely speeds run-time execution, it also tends to slow software development—but not if the key routines have already been written.

Ariel has put together a collection of more than 200 routines for the Texas Instruments TMS320C40 digital signal processor, all written in assembly language, and all claimed to be 2–10 times faster than those found in competitive C language libraries. Called Pythagoras, the new library comprises vector mathematics, signal processing, and image-processing routines. Its vector math capability suits it well to digital audio, radar, and sonar applications, where a few operations are performed repetitively on large data sets.

Pythagoras is available for both PC (US $1296) and Sun ($1495) platforms. It is available now. *Contact: Ariel Corp., 433 River Rd., Highland Park, N.J. 08904; 908-249-2900; or* **circle 111.**

COORDINATOR: Michael J. Riezenman
CONSULTANT: Paul A.T. Wolfgang, Boeing Defense & Space Group

Forum

Superprocessor crossroads

Patrick Bosshart's statement in the Technology 1993 article on "Solid state" [January, p. 49] that the battle between advocates of superscalar and superpipeline design techniques "seems to have become a dead issue" because "high-performance processors are going to have to include both" glosses over several remaining points of interest in this area.

Both sides agree that superpipelining and superscalar design techniques are roughly equivalent routes to the same goals (Norman P. Jouppi and David Wall of Digital Equipment Corp.'s Western Research Laboratory have called this effect "supersymmetry"). Also, both sides agree that fetching and issuing enough instructions per cycle to feed separate integer and floating-point execution functional units does gain overall because these functional units have incompatible design goals and because there is overlapping integer computation in most floating-point code.

Beyond this, there is significant disagreement as to whether it is better to implement a fast process technology and to design fast latches (the approach used in the mostly superpipelined DEC 21064), or to implement a dense process technology and to design complex central control logic that supports small, simple, easily replicated functional units (the approach used in the superscalar Motorola 88110). The tradeoffs involved in the mix of the two approaches selected in an individual processor are still complex and interesting and seem likely to remain so for years to come.

John R. Grout
Urbana, Ill.

Greyhounds and rabbits

A long time ago when I was young(er) and even more impatient than I am now, I was listening to a talk on how the long-distance network, in the then Bell System, was going to continue to be analog "forever." I proceeded, on the spot, to write an allegory called "The greyhounds and the rabbits" to express the frustrations of a confirmed digital network advocate. The speedy, sleek greyhounds were the "digitalers," while the fast-breeding rabbits were the "analogers" (or analogres).

I will not go on with details of how the rapidly increasing capacity of the rabbit clan frustrated the (naïve) digitalers and prevented them from acquiring their rightful long-distance territory. It wasn't until the doggies learned to dig deeper in the sand (silicon) that they were able to produce the chips and fibers to fulfill their destiny. (Note: this allegory has never been published. I gave a banquet speech based on this theme at the Zurich Seminar in 1984—some 20 years after it was written.)

The drive to improve existing systems is natural, but incremental changes impede introduction of the new. Management of this transition must be the major focus of all the players in global information system evolution. This was not adequately noted in the January Technology 1993 issue. For example, the review of data communications failed to mention the advances in switched Ethernet that will affect the asynchronous transfer mode (ATM) takeover.

Further, the exploitation of the embedded copper plant by [the digital services of] ADSL and HDSL (and video compression) is a current example of the deferment of a new technology—fiber to the home—because useful new services (video) may be offered over existing facilities. Many believe that this delay is temporary and, by whetting the appetite of the consumer, will actually stimulate the move to even wider-bandwidth services over fiber. Work on Nx64Kb/s multiplexers and switches confirms service capabilities competitive with ATM. Sorting out these riches is the modern version of the "greyhounds and the rabbits." Of course, the sorting will be done in the cauldron of the marketplace.

(Incidentally, in the above noted article, ADSL was spelled out as asynchronous digital subscriber loop. The correct label is asymmetric digital subscriber line; similarly, HDSL should have been referred to as high-bit-rate digital subscriber line.)

M. Robert Aaron
West Palm Beach, Fla.

Pavement power

I read with fascination the November articles about electric vehicles. One thing surprised me, however; nowhere is the possibility of electrifying the roads discussed. If you look at the most successful electric vehicles today, they are trains. These do not use batteries but rather pick up power from rails.

Superficially, cars are quite different in that they offer each driver the independence to roam on random routes at arbitrary times. Yet, if you actually look at the typical usage of vehicles, there is a huge amount of mileage put into commuter journeys that follow standard routes. Cities have a network of freeways that are sought by anyone traveling more than a few kilometers.

In the articles, I got the impression that the major goal for successful electric vehicles is to serve as commuter vehicles in an urban area, with a range of up to 300 km and predictable recharging arrangements. Would it not be equally practical to have vehicles with a much shorter independent range in an urban environment where the freeways offer electrified lanes?

To be sure, electrifying a freeway would be quite a challenge. It may be practical only in ice-free cities, and would require innovation in safety, automatic engage and disengage, billing, and compatibility with conventional vehicles. Still, it seems no less reasonable than the challenge of battery development. It offers a potential for far greater efficiency, since no matter how good batteries become, there would still be a significant weight reduction in every vehicle if they need to have less of an independent range.

John G. Bennett
San Mateo, Calif.

The well-read EE

I write to express my dismay at the book review "Radio history as biography" [November, p. 8]. The reviewer, Hugh G. J. Aitken, has again invoked the old canard (or should I say chestnut since our knowledge of language is supposed to be so bad?) about the nonreading habits of EEs. Does this imply that medical doctors, lawyers, architects, financiers, physicists, chemists, and others *are* book-reading types?

I, frankly, am tired of being singled out as "nonintellectual," "nonreading," "nonliterate." I have lots of friends among all professions, including EEs. I see no distinction between their interest in, and knowledge of, the world around them, history, literature, and so forth—let alone their reading habits. What does it take to convince the world at large that we are not a group of shy, non-people-oriented, technical nerds?

Mischa Schwartz
New York City

Ethics and the law

I read "It's the law, but is it ethical?" by Donald Christiansen [September, p. 25] with interest and anguish. I have been a member of the IEEE since my undergraduate days in the mid-60s, and I have always been concerned with the issue of professionalism and engineering. Over the years my interests have turned to economics and law, but I still

(Continued on p. 61)

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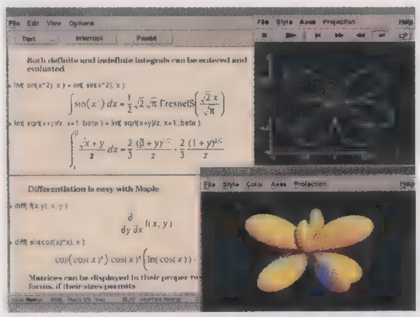

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HOW ENGINEERS VIEW THEMSELVES

Looking back a mere five years confirms that little is the same. Internationally, the Soviet Union and the Cold War no longer exist, leaving a vacuum that threatens to make defense and aerospace engineers an endangered species. In the United States, the economy is shaky, causing electronics companies to lay off more and more engineers. Yet some news is good: high technology is in the ascendant, giving hope to those who work in telecommunications and information technology.

But EEs today, like those five years ago, still worry about respect and remuneration, eroding skills, and what they see as interference from bean counters and managers.

Against this motley background, *IEEE Spectrum* asked a representative sample of its readers to look at the last five years in terms of their self-images, their jobs, and the rapidly evolving environment in which they work. The result is a detailed and up-to-date enlargement of the electronics engineer's world as he or she sees it.

This direct-mail reader study, conducted in November 1992 by Erdos & Morgan/MPG of New York City, expands on one that was done in 1988. The earlier poll dealt with self-image and job satisfaction; the new one is more comprehensive, covering those topics plus corporate restructuring, work performance, and analyses of the past and future of the engineering profession.

The six-page questionnaire was sent to 2000 U.S. IEEE members, excluding students and retirees. (The 1988 survey polled *Spectrum* readers through a questionnaire published in the magazine and therefore sampled IEEE members worldwide.) Of those 2000 sent out, 15 of the surveys could not be delivered, and 656 were filled out and returned, yielding a response rate of 33.1 percent. In addition to answering questions by checking appropriate boxes, the respondents were asked to offer comments. (In the 1988 worldwide survey, *Spectrum* tallied 769 answers, and U.S. engineers made up 93.5 percent of the respondents.)

Howard Wolff Contributing Editor

Michael Hirst, Bill Simone

In some ways, the portions of the survey that deal with images and perceptions of the profession and job satisfaction are most enlightening because they can be generally compared with responses to the 1988 survey. (Where percentages do not add up to 100 percent, questions included multiple answers or totals were rounded off.)

Despite hard times and complaints heard in the industry of vanishing job security, job satisfaction is high. Almost 40 percent are more satisfied than they were five years ago and 22 percent indicated that they are very satisfied. Less than 36 percent are less satisfied. One trend that stands out sharply is that more EEs of the 1990s generally believe that they are held in higher esteem than did those of the 1980s. In several categories, the respondents indicated that they are better portrayed and appreciated.

For example, the number of EEs who felt that the public often has no understanding of what an EE does is basically unchanged at 80 percent, from the 1998 figure of 82.8 percent. But the percentage of those who believe that movies, television, and other media often misrepresent engineers has shrunk considerably in five years. In 1988, 60 percent believed that to be often true, but in the new survey the proportion is reduced to 49 percent.

Despite (or because of) hard times, job satisfaction is high: more than 60 percent are more satisfied now than five years ago

Another big shift is in the number who believe that EEs often are not very good at explaining their jobs to nonengineers. In 1988, 43 percent believed that to be often true; now, the total is just 33.2 percent. Similarly, the percentage who believe that it is often true that EEs have poor writing and communication skills is way down: to 22.9 percent today from 38.1 percent in 1988.

Moreover, a mere 17 percent now say that the stereotype of EEs as a socially awkward individual is often true. That is a marked reduction from the 24.9 percent who bought into the "nerd" image in the 1988 survey.

Electrical engineering is a tougher field than other engineering fields, according to almost 94 percent of respondents, who said that statement was either often or sometimes true, and more than 89 percent of those same groups said that engineering has a greater impact on society than do other professions.

LIKING THE JOB. Job satisfaction is another area that is a pressure point for many EEs and was also covered in the 1988 survey. In 1992, however, not only was the category subdivided into more areas, but the question was rephrased. Rather than simply ranking the factors that contribute to job satisfaction—as they did in 1988—respondents were asked to compare the items on a list of activities and say how important each is to overall happiness at work today versus five years ago.

Then as now, the most important element in job satisfaction is the opportunity to be creative—outranking pay, despite the weakened economy. As one respondent commented, "Engineering disappoints, on average, when measured through prestige/money, but rewards through its dynamism."

In the 1988 survey, about 65 percent ranked creativity as the topmost factor in job satisfaction. Today, 58.4 percent believe it is even more important than it was five years ago, 10.3 percent deemed it less important, and 24.4 percent considered it about the same. One respondent offered the opinion that "creativity is less and less due to R&D because of the decrease in R&D investment. [There should be a] method to account for those invisible technological rewards."

Along with the opportunity to be creative, salary matters more today than five years ago to the majority of respondents, though being creative is considered more important by a greater proportion. But the salary picture has left many EEs bitter. One respondent wrote, "With the downturn in

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the economy, engineering wages and benefits are being scaled back drastically. Today [we] will be lucky to preserve what [we] have."

Nearly 43 percent of respondents do not think their salary has improved compared with salaries of other engineers, while 32 percent think it has. But more than 52 percent do not think their salary has improved compared with what other professions earn. In any case, about 53 percent of respondents report that their salary has kept pace with their expectations. The average salary for respondents is US $64 000 (median: $62 700), and the largest single segment, approximately 43 percent, earns between $50 000 and $74 999.

Standing third on the list of contributors to job satisfaction are diversified job responsibilities, with 47.6 percent of the engineers saying they count for more now, 11.7 percent considering it less important, and 30.4 percent ranking it about the same. Slipping to No. 4 in 1992 from the runner-up spot last time is personal growth potential. Now, 45.2 percent say it has grown in importance, 17.7 percent reckon it has diminished, and 28.6 percent say it is about the same.

A good peer relationship is in fifth position. Calling it more important now than it was a half decade ago were 43.2 percent of the readers responding, while 42.3 percent decided it is about the same. Significantly, a mere 5.3 percent considered it a less important factor.

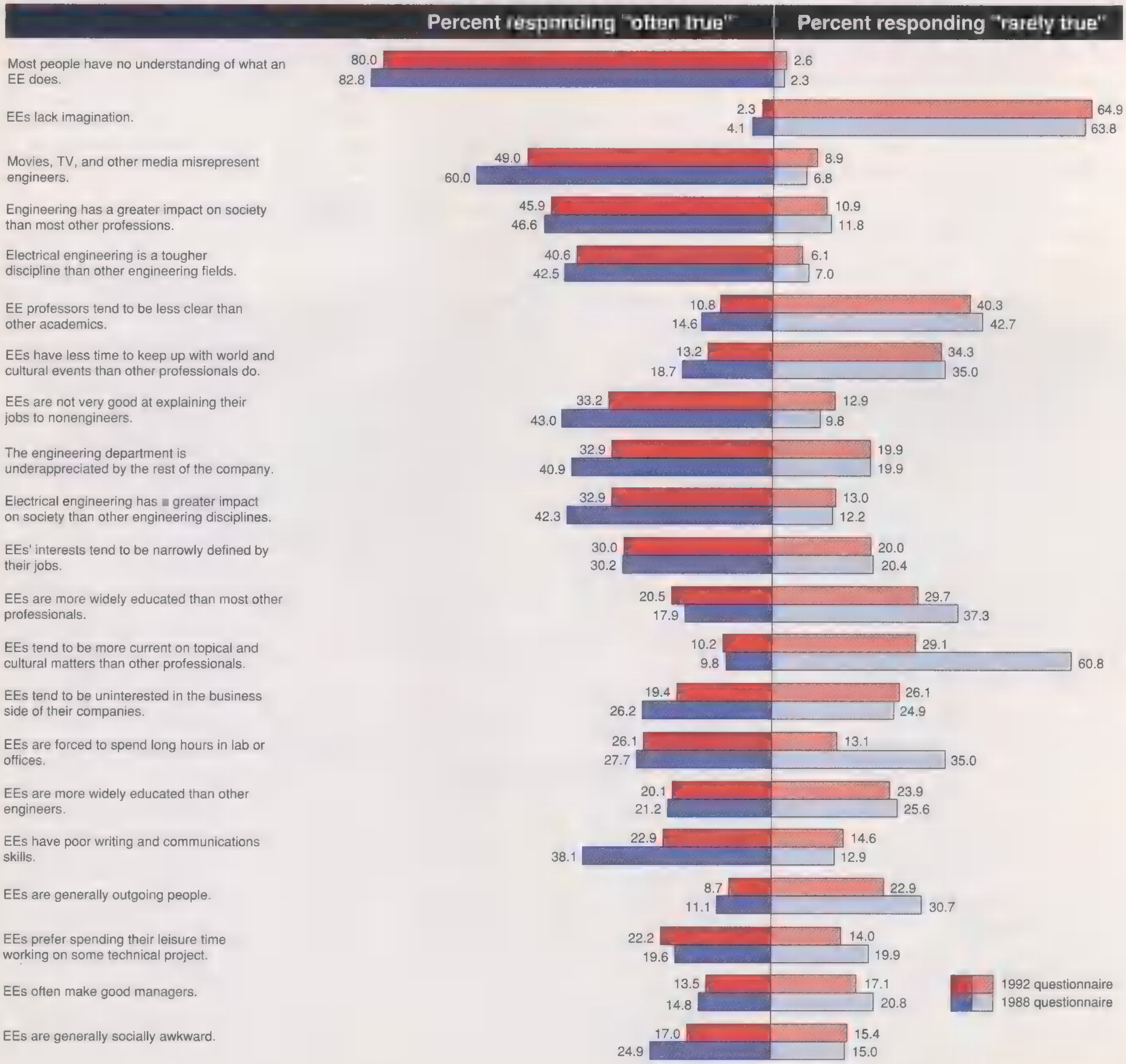
Underscoring the need for good relations, a respondent commented, "the advance in technology will inevitably lead to specialization in a narrower field. Multidisciplinary teamwork is essential. The engineers should be trained as team players."

Back in 1988, 45 percent of the respondents considered the company's technical reputation very important, enough to rank it seventh. Now, 41.8 percent believe it has taken on added importance, 34.9 percent say it is about the same, and 13.8 percent say it is less important.

PAPERWORK PROBLEM. A key component of job satisfaction for the average EE is how much time is spent on activities ranging from research to attending meetings and conferences to paperwork.

Asked whether they spend more, less, or about the same amount of time in those pursuits than they did five years ago, the survey came up with some surprising conclusions—expecially in light of the advances of the last five years in software

How electrical engineers [illegible] themselves



tools calculated to take much of the drudgery out of the engineer's work. The responses show that the three areas in which time spent has risen sharply all have little to do with actual engineering.

The biggest increase was in conferring with others, where 45.3 percent said they spend more time, 14.6 percent believe they spend less, and 30.6 percent said it is about the same. Routine paperwork consumes more time for 45.2 percent, less for 14.8 percent, and about the same for 29.9 percent. And 43.9 percent said they spend more time at in-house meetings, 17.4 percent see that activity diminishing, and 27.5 percent said it is about the same.

As to how respondents rate their work, time spent on doing research is a key factor in job satisfaction. A significant proportion of respondents (27 percent) are spending less time on research than five years ago and over 72 percent of them are unhappy about it. On the other hand, pleasure in the job increases for 85 percent of those who spend more time on research.

More respondents are spending more time on development and fewer are spending less, compared to five years ago—25.6 percent vs. 20.6 percent. Job satisfaction increased for 78 percent of those who are spending more time on development, and decreased for 76 percent of those who said they are spending less.

On design, about an equal number (ranging from 23 percent to 26 percent) said they were spending more, less, or about the same time, compared to five years ago. Again, the level of job satisfaction increased for more than 80 percent of those who are spending more time on design, and decreased for nearly 70 percent of those who are spending less time.

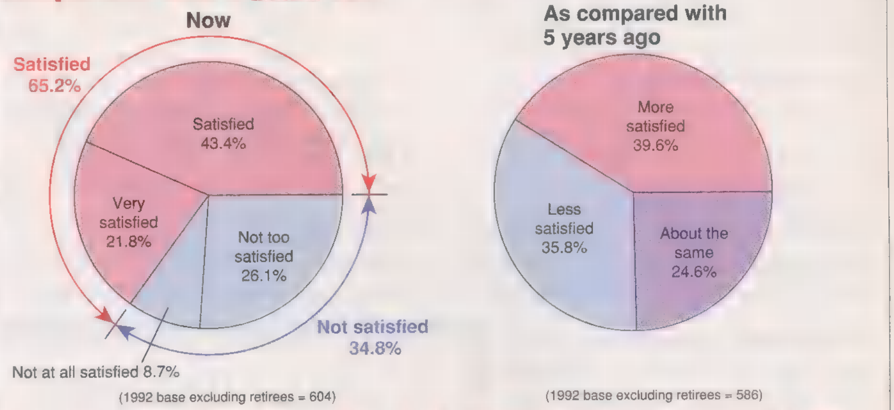
MORE MEETINGS. More than 43 percent said that they are spending more time in conferring with others, attending in-house meetings, and handling routine paperwork. Conferring with others has a positive effect in job satisfaction for more than 60 percent of those who are spending more time—and a negative effect on about 78 percent who are spending less time.

Not surprisingly, in-house meetings and routine paperwork tend to drive job satisfaction down for more than 65 percent who spend more time in meetings, and down for over 80 percent of those who spend more time on paperwork.

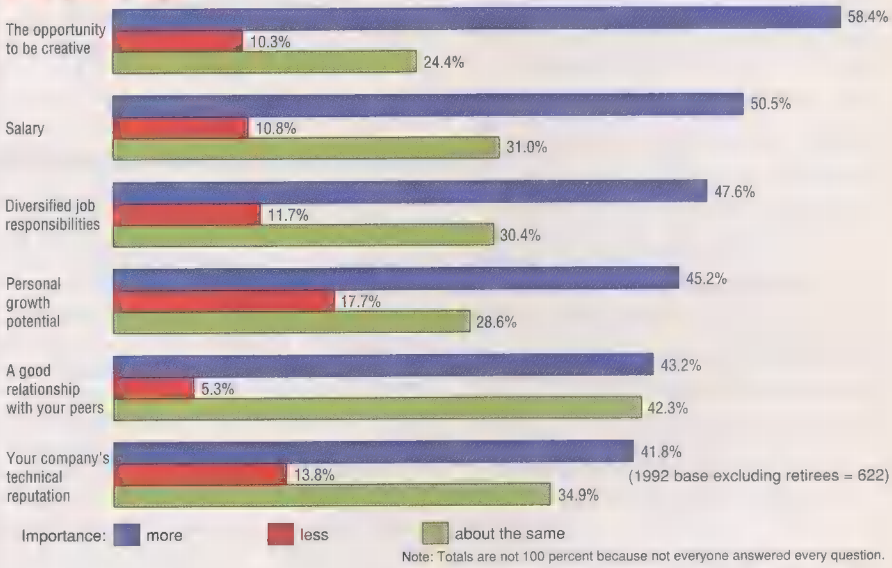
Job satisfaction increased for the majority of those who spend more time in reading to keep up with their field, educating others, taking job-related courses, supervising others, and attending external meetings and conferences. Interestingly, job satisfaction increased for about 48 percent of those spending more time in supervising, but decreased for nearly 25 percent.

Among respondents at the 29.3 percent of companies that are still significant military contractors (more than 25 percent of products and/or services), 18.2 percent said

How satisfied EEs [redacted] with their job now and in comparison with 5 [redacted] ago



What factors matter more now to job satisfaction compared with five years ago



their employer has a clear plan for conversion to commercial products, 28.4 percent have such a plan in part, 44.9 percent—almost half—have no plan, and in 8.5 percent of the cases the respondents did not know.

DOWNSIZING HURTS. But it is not just the end of military work as two generations of EEs have known it that hurts; also adversely affecting today's engineer is the trend to downsizing of companies. Some 62 percent of respondents said that their companies have restructured in the past five years, entailing layoffs, staff cuts, and firings.

Commented a respondent: "The restructuring of corporate America has resulted in loss of good talent and demoralization of survivors. Management has learned nothing from this."

Not only that, but 61 percent of the respondents work for companies that have downsized, and 45 percent of these have been personally affected. Most, 28.4 percent, were reassigned, with the majority landing in equivalent positions; 8.3 percent were laid off. The median number of employees laid off by respondents' employers in the last five years was 484, and a startling 37 percent of the companies laid off 1000 or more employees.

"I wish I was more upbeat," wrote one respondent on his questionnaire, "but I've seen too many EEs jockeyed around—transferred, laid off—[so] that they rarely build their pension funds."

Not everyone who moved to a lesser-paying job is unhappy. "I was able/willing to change from applied engineering research management to hospital-oriented medical research and absorb a 30 percent salary cut with the possibility of improved salary in the future and a definite need for my work for society," said another respondent.

TAKING PRIDE. Asked to look back over the past 25 years in order to select the profession's greatest success, 29.1 percent of the survey respondents chose the development of computers of all sizes, including microcomputers and desktop models. Right behind in their estimation, with 19.6 percent of the citations, was bringing technology to the public, along with automation, consumer products, and consumer electronics.

Also rated highly were microelectronics, microprocessors, and microchip technology

miniaturization, mentioned by 11.5 percent. These were followed by the Apollo/space program, moon landing, and space exploration, 9.8 percent; and Comsat, satellite development and transmission, and communications development, 6.6 percent.

At the other end of the spectrum, the biggest disappointments of the past quarter century for 17 percent of those responding were the disappointing growth of the automation sector in the United States and the loss of technological stature and leadership to Japan (an additional 3 percent cited non-U.S. competition and dominance in general).

TOUGHEST CHALLENGES. Looking ahead, two areas are held above all others to offer the greatest challenges to the profession. For 12.8 percent of the respondents, automation along with the technology and new products needed for managing information present the most formidable obstacles. For 12.2 percent, it is the need for effective and continuing education to keep up-to-date.

Judging from replies to the questionnaire, a whole range of reactions are triggered when education is mentioned. One respondent used the opportunity to take academia to task and wrote, "The current tenure process at universities places too much emphasis on the ability to obtain research money. That is, academia has become just another business focused on the bottom line. The emphasis on research rubs off on students who esteem research and dislike manufacturing (leading to many of our current problems with manufacturing, compared to other countries)."

Another way to keep engineers current is to teach them how to communicate with one another, suggested a respondent who wrote, "In work situations, it seems that technical matters comprise about 10 percent of the job. The other 90 percent is interpersonal relations and group behavior. Perhaps more emphasis in education should be placed on development of these skills."

Who should do the teaching to keep engineers up to date? Their peers, answered one EE, who said that EE education needs to be radically changed before it can be considered professional (comparable to MDs). He called for "education by experienced engineers—not academics who cannot correlate to engineering."

The biggest problem for 9.7 percent is conversion from defense to peacetime markets, and a closely related matter—revitalizing U.S. industry and developing markets for technology products—was considered a top challenge by 9.1 percent. Keeping engineers employed was cited by 8.1 percent.

GLOBAL VIEW. One respondent suggested that a world view of engineering is at least part of the answer. "Our profession must develop global consciousness, social involvement, and communications excellence (telling and listening) for every member."

As in the 1988 survey, the most important element in job satisfaction is the opportunity to be creative

Wrote another, "The current world market and economic situation will force all companies to restructure and modify operating controls. The only ways to react to this situation is to concentrate on education and technical advancements to society and manufacturing." And, said one respondent, "Engineers need to be more concerned with the social implications of their work."

Can the engineering profession meet future challenges? The answer is a resounding yes, with 73.2 percent of the respondents confident that engineers definitely have, or probably will have, the ability to do so. Only 15.8 percent are pessimistic, believing that engineers probably will not (13.8 percent), or definitely will not (2 percent), be able to face up to the job.

Furthermore, most of those replying—55.7 percent—believe they will be involved in the challenge, while just 22.9 percent do not expect to have a role and 21.4 percent do not know.

STILL NO RESPECT? Fewer respondents today would be willing to recommend a career as an EE than would have done so five years ago. Some 72.5 percent would encourage a family member or friend to enter the profession; 27.5 percent would not. But 82.8 percent said they would have offered such encouragement five years ago.

Still, the future looks darker to many respondents than it did five years or a decade ago. As one commented, "I'd encourage someone to go into engineering today for the technical rewards—it's very satisfying that way. But as far as personal satisfaction, forget it—engineers get no respect. Upper management in most companies I've worked for have treated engineers sort of like high-priced plumbers."

A grim picture came from a December 1990 EE graduate. He wrote, "After 1200 résumés and about 30 interviews (in every one of which I was asked, 'What do you see in engineering's future?'), and [in which] all the interviewers said, 'You're young and can still change careers,' I gave up and went into insurance. Since July 1992 I have sorted mail for $5 an hour, but I'm not complaining. Everybody else I graduated with is unemployed, flipping burgers, [or] delivering pizzas. At least I have medical coverage."

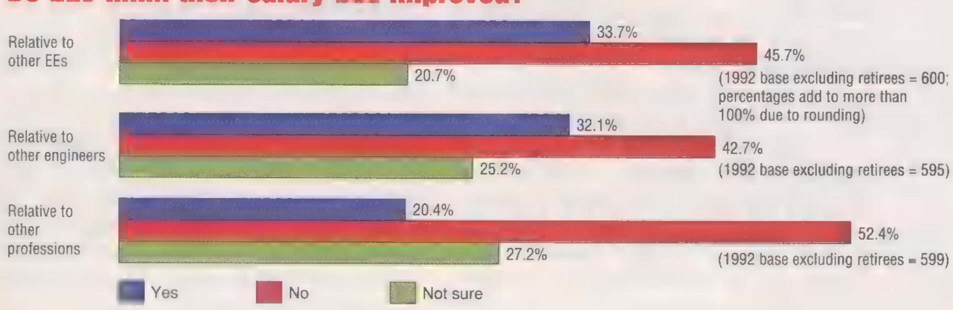
Perhaps the answer, in the view of one respondent, is more extensive training. "My training at Johns Hopkins in the late 1940s was very broad-based," he wrote, "including chemistry, physics, surveying, thermodynamics, etc. I believe that this broad background greatly increases my ability to see and comprehend the big picture."

Undiscouraged was the engineer who responded, "I think we should be optimistic about the future provided [we] realistically appraise our situation and apply ourselves to the problems at hand. That includes a political awareness and involvement in those issues affecting the profession."

Overall, what is the broad message delivered by the *Spectrum* survey? It illustrates a profession in transition in a changing world. Economic and political forces have remolded the occupational shape of engineering, sometimes causing individual dislocation and anxiety. At its most acute, this overview leads to outlooks such as this respondent's: "The 1990s will be a decade of misery for engineers as the Defense Department declines and nothing replaces it."

But the other side of the coin shows a profession that has spawned and continues to generate an era of technological creativity. It is one that promises to continue transforming U.S. life into the foreseeable future, carried forward by engineers who love their work and have tremendous confidence in their abilities to meet any challenges. As one respondent summed up this perspective, "Electrical engineering could become the most creative and exciting profession ever in the next 25 years. The potential is almost beyond imagination." ◆

Do EEs think their salary has improved?



Competitive measures

Technology will not advance as freely as before unless more attention is paid to metrology, a pillar of national competitiveness

In the 1980s, as global competition for high-stakes, high-technology markets intensified, theories and analyses explaining notable successes and failures abounded. The attempt to comprehend the performance of products, companies, or even entire nations—and to predict what would be required to compete globally in the high-tech markets of the future—seemed to take every possible factor into account. The roles of consortia, precompetitive research, manufacturing technologies, automation, management structures, the empowerment of shop-floor employees, and even the salaries of chief executive officers were but a few accorded exhaustive treatment in books, articles, and reports.

But somehow, and notwithstanding the tens of thousands of pages written on competitiveness in the last five or six years, one crucial factor has indeed been overlooked: metrology.

What does metrology—the science and technology of measurement—have to do with prosperity in competitive high-technology markets? One might as well ask what tuning up has to do with the success of an orchestra, or why stopwatches are of any use in Olympic training.

Most people would agree that quality is a cornerstone of competitiveness. Yet quality is often a function of manufacturing precision, which is in turn a function of dimensions, tolerances, and, in the final analysis, measurements. One example that many people can relate to concerns the automotive industry. Several years ago, when it was the fashion to compare U.S. automobiles unfavorably with those from Japan, a recurrent factor was differences in how their doors opened and closed.

The U.S. car doors, on average, required 76 ± 58 newtons to open, while the Japanese doors took only 31 ± 9 N. In the worst case for the U.S. vehicles and best for the Japanese ones, this difference corresponds roughly to a factor of six in perceived quality (134 N versus 22 N). The variations in force correspond to variations in the tolerances of the dimensions of door assemblies, which correspond to variations in dimensions of panels from which the doors are assembled, which correspond to variations in the dimensions of the dies with which panels are stamped from sheet metal.

For all its importance in modern manufacturing, the term "metrology" is, unfortunately, likely to be associated with artifacts—the platinum-iridium meter bar and the kilogram mass in Paris, for example. But the reality is that metrology is a sophisticated and dynamic endeavor, and one upon which technological industries increasingly depend. One need not be an expert in semiconductor fabrication or laser surgery to realize that success in either field demands accurate measurements.

Still, it is rare to read or hear in any country about the vital need to maintain a strong national position in metrology. Meanwhile, commercial and scientific applications are pushing the state of the art in measurement techniques in most advanced countries, particularly the United States. It is becoming steadily clearer that if technology and commercial industries are to go on advancing unfettered in these countries, more attention will have to be paid to metrological research and support.

> U.S. funding for R&D in metrology has hardly increased for the last 15 years

In the United States, for instance, annual spending on research and development, both corporate and Government-funded, has risen from around \$85 billion to around \$170 billion over the last 15 years. At the same time, laboratory R&D at the National Institute of Standards and Technology (NIST) in Gaithersburg, Md., has held essentially constant at roughly \$170 million.

In most advanced countries, metrology, like basic research, has long been recognized as a responsibility of the central government. In France, for example, standards, measurement, and metrological research are carried out by the famed Bureau Internationale de Poids et Mesure in Sèvres; in Germany, the corresponding organization is the Physikalische-Technische Bundesanstalt (PTB). In Japan, most of this activity falls within the purview of the Ministry of International Trade and Industry (MITI), mainly in the National Research Laboratory of Metrology, under MITI's Agency of Science and Industrial Technology.

FEDERAL CASE. In the United States, Congress established NIST's forerunner, the National Bureau of Standards, in 1901, charging it with providing the measurement techniques that U.S. industry would need to function in a technological environment. NIST still develops fundamental standards for base units (length, time, and electricity, for example). But the lion's share of its efforts is now devoted to work on units derived from the fundamental ones and to supporting specifications that matter to U.S. industry.

Nonetheless, a brief review of the status of metrology in just the length category reveals the precarious state of this critical area of research. Take quantum-dot, -wire, and -well devices, for example. These devices owe their unique and extremely useful properties to their ability to manipulate individual charges, typically electrons. In fact, some experts believe these devices will be the garden-variety electronic components of the next century. But making them will require manufacturing tolerances and measurements as yet unavailable.

For example, to maintain 5 percent tolerance in a quantum-dot diode 10 nm in diameter—a parameter already realized in U.S. and Japanese laboratories—production measurement would need an accuracy four times better than the tolerance, or 0.125 nm. Then NIST, for ease in transferring this kind of production measurement accuracy, would have to be able to make measurements four times more accurate, to within 0.03 nm.

Measurements such as this would be on an atomic scale and are almost unimaginable at present. The present limit on accuracy in length measurements is about 1 nm, realized by NIST's molecular measuring machine. In other words, metrological support of the manufacture of this kind of quantum device will require accuracies

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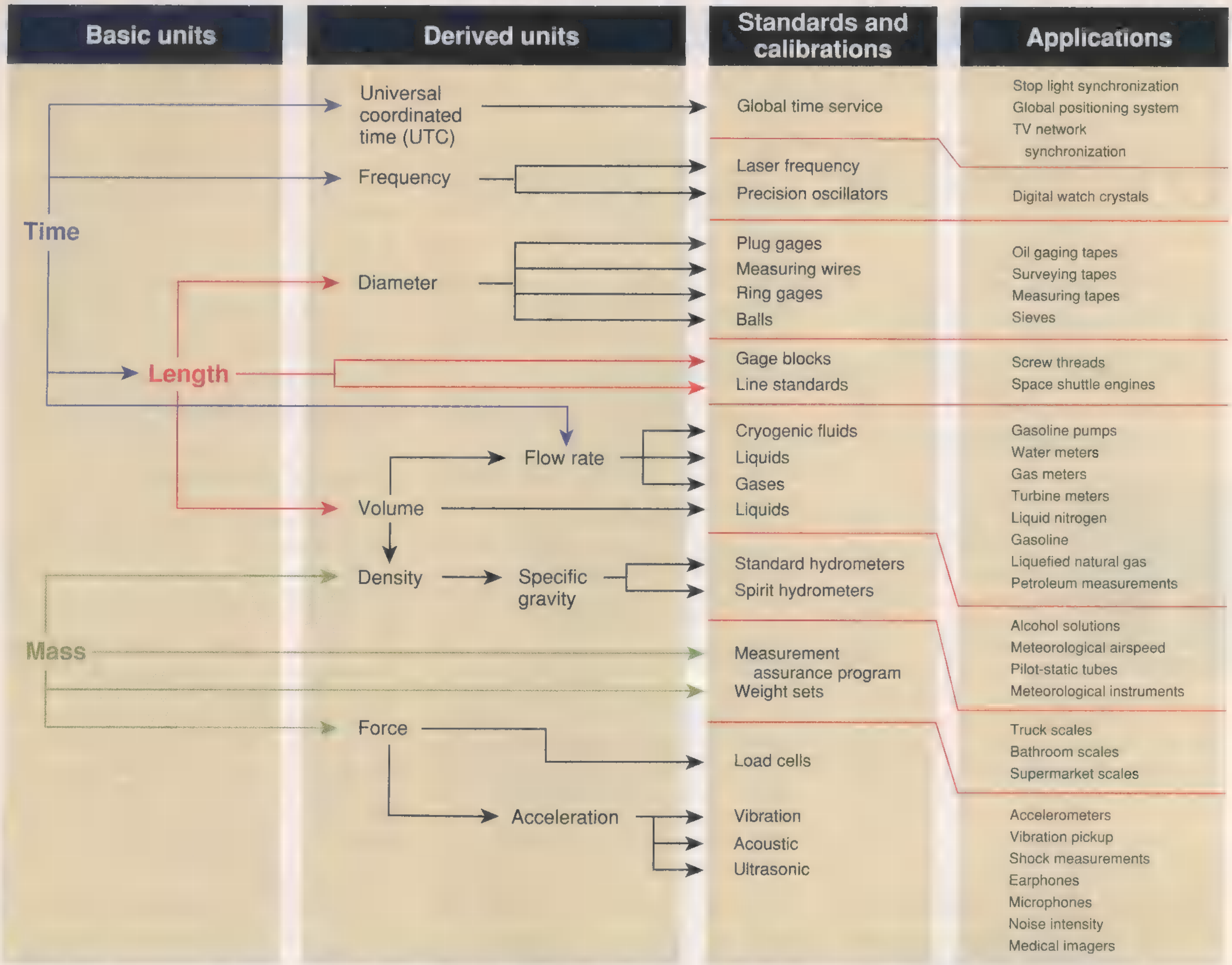


[1] All standards are derived from a few fundamental units, good examples of which are time, length, and mass. This measurement pyramid, employed by the National Institute of Standards and Technology, shows the measurement transfer chain, from basic units to those derived for everyday applications.

more than 30 times better than the present limit. Herculean efforts will be needed if such accuracies are to be achieved.

More conventional forms of microelectronic fabrication will also demand much more precision from metrological support. Consider the emerging projection lithographic techniques exploiting point X-ray sources. Most experts believe the aspheric X-ray mirrors for these systems will have to be accurate to within 1 nm; the optical techniques for producing—or measuring—this kind of accuracy do not yet exist.

Another burning issue in length metrology concerns its support for the magnetic data-storage industry. The pole-tip of a magnetic head is specified to be recessed from its surroundings by less than 0.025 μm, and the industry requires inspection-measurement systems to be calibrated to a factor of 10 better—that is, 2.5 nm.

Normally, this kind of measurement is performed by a profiling microscope, which is calibrated by step-height standards. With the minimum factor of four times better for the NIST step-height standard, this requires accuracy of 0.6 nm, about twice as good as what is possible right now. Although the industry has been making do with the step-height standards, these systems will certainly cease being even marginally adequate as tolerances shrink.

In fairness, it should be noted that although NIST does not have all of the standards and measurement methodologies necessary to meet some current and future needs, the institute is working hard in key areas. Hopefully, enough resources will be allocated for the institute to do a timely and creditable job.

Good examples of the need to support time and frequency metrology are plentiful in the telecommunications industry, which is relying more and more on digital, optical-fiber systems requiring highly precise and coordinated timing between sender and receiver. The precision of this coordinated timing must increase as the data rates and traffic volumes increase. Lost information, typically in the form of dropped bits, is the penalty for imprecise timing between sender and receiver.

To explain how this happens, a little background is in order. Although the word synchronization, implying the matching of time, is commonly used in digital telephony, it is not correct, strictly speaking. The digital telephone system is actually based on syntonization, the matching of frequency. In digital packet-switched communications, the data are buffered at intermediate points, with some extra bits (called stuffing) in the packets to allow for different clocking rates. If the clocks at the receiving and transmitting ends are poorly syntonized (have excessively different frequencies), the packet buffers overflow and bits are dropped. This is usually how data are lost.

In the Synchronized Optical Network (Sonet), now being installed in parts of the United States, the syntonization requirements are such that frequencies must match to within one part in 10^{11}—10^{12}. Such a requirement already pushes the state of the art in timing and frequency-matching. The problem is that some telecommunications experts now feel that if the da-

ta requirements for communications systems keep on escalating, true synchronous operation will eventually be required. This will impose even greater demands than those associated with Sonet.

PHYSICS PRIMER. Most metrological units are derived from a very small number of base units. As anyone who paid attention in physics class knows, acceleration is derived from length and time; work, from length and force (the latter from mass and acceleration). Each unit has associated with it an internationally agreed-upon technique for defining that unit, as well as one or more secondary measurement techniques, which are developed and calibrated by agencies such as NIST to make measurement more convenient [Fig. 1].

To take a simple example, temperature is defined in terms of black-body radiation. Obviously, if you want to know the temperature of your oven, you would rather not have to rely on a black-body device. Here a secondary measurement device—a thermometer—is preferable. NIST and standards organizations in other countries develop and calibrate such secondary measurement techniques.

In effect, most metrological applications involve a measurement chain, from a highly accurate, fundamental standard to field measurements made routinely in support of industry or commerce. As an example, take electric power. NIST is the source of all U.S. electric power and energy measurements, and it calibrates about 100 transfer-standard meters for the country's utilities every year to an accuracy of 0.005–0.05 percent. These meters are used to calibrate test instrumentation, accurate to 0.1 percent, which is used to test and calibrate the meters affixed to every home.

By state law, these meters must be accurate to within 2 percent, although the general utility practice is to provide meters with less than 0.5 percent error. Even small errors, in this case, can translate into huge sums of money. There are some 111 million consumer meters installed in the United States, which monitor the sale of some $180 billion worth of electricity every year.

SHORTER CHAIN. Increasingly, companies are eager to see the measurement chain reduced; they would like to realize standards in their own laboratories with accuracies approaching those of the fundamental standards. In particular, industries working at the cutting edge of electronic instrumentation have found the need to maintain standards in their own calibration laboratories that are virtually as good as NIST's.

One such standard is the volt. Fundamental standards in electrical metrology are being realized more and more through quantum-mechanical effects, which govern the physical behavior of matter on the atomic or sub-atomic scale. Accordingly, the volt is now defined through the use of the Josephson effect, which refers to the tunneling of electron pairs through a weak connection between superconductors; and Josephson-junction array standards are used to define the standard volt.

NIST has already provided 1- and 10-V Josephson-junction array standards to several U.S. companies and laboratories, and is working with other companies to develop a commercial U.S. source of array standards. Of course, different companies need such precision for different reasons. One of the more dramatic cases of a commercial need for access to the highest-level standards involved Hewlett-Packard Co.

Just as NIST was completing development of the 10-V Josephson-junction array, the Palo Alto, Calif.–based company was working on a high-precision multimeter, model number 3458A, and needed a way to check the instrument's linearity. The best conventional standards available had an accuracy of one part in 10^8—not good enough for the company because that happened to be the accuracy they were aiming for with the new product. Only the developmental 10-V array system, with its accuracy of one part in 10^{10}, could do the job.

This 10-V standard is a microelectronic chip fabricated by means of the same basic processes (lithography, etching, and so on) used every day for countless commercial integrated circuits. The chip serves in effect as a frequency-to-dc converter, changing a very precise frequency (that of the easily accessible Loran-C precision frequency reference) into a useable voltage. Input microwave energy is fed to a number of arms, or strings, of Josephson junctions, each terminated in a characteristic impedance to prevent reflections back up the arm. The goal is to expose each junction to the same microwave environment as its neighbors. The dc potential is developed across large pads at the top and bottom of the chip.

> An unexpected offshoot of the new volt and ohm quantum standards may be the 'electronic' kilogram

In round numbers, the NIST chip incorporates 20 000 junctions and constitutes one of the most complex Josephson-junction chips ever built. The latest versions are fabricated using a niobium-trilayer superconducting technology.

After learning of the array project, Hewlett-Packard approached NIST for permission to use the developmental 10-V system to evaluate its multimeter. The product's accuracy was confirmed, and shortly thereafter, HP announced availability of the precision multimeter. Later, the company acquired a 10-V array standard from NIST for production-line measurements.

For now, however, the Hewlett-Packard case remains the exception rather than the rule, and for most of U.S. industry the voltage measurement chain is somewhat longer. At the top is the NIST Josephson-junction array standard. It is used to calibrate either the zener-diode reference standards or a Weston electrochemical cell, both of which laboratories employ as voltage standards. NIST uses two groups of working cells as a double check, along with a calibrated resistive divider for the zener references, to calibrate the zeners or the standard cells for laboratories all over the United States.

Each of these references has advantages and disadvantages for commercial applications. The zeners are noisier but more robust, and the standard cells are quieter but easily disturbed by electrical or thermal changes.

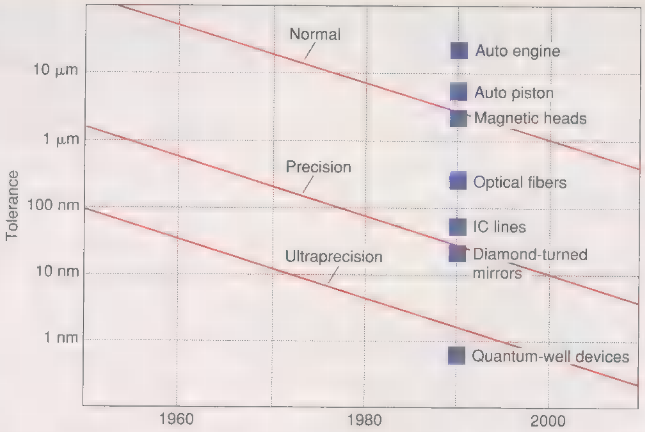
Because of the industrial demand for higher accuracy, several Josephson-junction array systems are already being used in industrial laboratories and in those of the departments of Defense and Energy. Proper operation of these systems can improve both precision and accuracy by several orders of magnitude.

THE ELECTRONIC KILOGRAM. The volt is not the only electrical unit now defined through a quantum standard. The ohm is also defined in terms of an effect, called quantized Hall resistance, which was discovered only 15 years ago. The effect is associated with the fact that electrons confined to two dimensions, as in a metal oxide semiconductor structure in a magnetic field, have discrete energy levels. The Hall voltage of such a structure shows plateaus as a function of gate voltage. This corresponds to a Hall resistance that equals Planck's constant divided by the square of the electron charge.

One unexpected side benefit of these new resistance and voltage quantum measurement standards may be yet another standard, for mass, which might be called the "electronic" kilogram. Right now, the standard ampere is defined in terms of how much current must flow in two wires in order to produce a known force between those wires. NIST implements this definition by balancing the electromagnetic force on a wire coil in a magnetic field against the gravitational force on a standard mass.

Since the ampere can be defined in terms of the volt and ohm (which are in turn determined by quantum effects), the ampere balance could be used, in reverse, to determine mass. Achieving this new goal would have the highly desirable effect of replacing the only remaining artifactual stan-

[2] These manufacturing tolerances are the characteristic, or mean [red], actually (or predicted to be) achievable in the various dimensional regimes. In seven critical manufacturing areas, different tolerances [blue squares] were demanded in 1990.



dard among the fundamental units. The challenge to experimenters is to identify all possible factors that can affect the measurement even below part-per-million levels, so as to eliminate, minimize, or compensate for these influences.

CRITICAL DIMENSION. Perhaps even more than electrical metrology, dimensional metrology is closely related to industrial competitiveness. Exactness of dimensions is fundamental to the manufacture of all kinds of goods, including airplanes, automobiles, videocassette recorders, communication systems, and computers.

The basic dimensional unit is the meter, defined as being the "length of path travelled by light in vacuum in the time interval 1/299 792 458 of a second." Although the meter is defined in terms of the speed of light, the *de facto* standard for dimensional metrology is realized by a stabilized helium-neon laser. The degree of accuracy attainable depends on the stability of the laser.

For an unstabilized, free-running helium-neon laser, overall length measurement uncertainty is at best about one part in a million, because of the uncertainty in the vacuum wavelength of its red-orange light. Even with stabilized lasers, uncertainties in the value of the index of refraction of the air along the laser beam path impose a limit of about one part in 100 million. Similarly, uncertainty in the international temperature scale at the standard temperature of 20 °C constrains accuracy to no better than about one part in a billion (10^{-9}). Finally, even the best available iodine-stabilized helium-neon lasers have uncertainties on the order of 1 part in 10 billion.

Of course, this kind of accuracy is not called for in every industrial application. Consider the trends on tolerances in the machining industry. The dimensional measurements in this industry can be divided into three regimes [the specific tolerances associated with each are shown in Fig. 2]:

- Normal, which includes products made by conventional milling and turning and measured by coordinate measuring machines.
- Precision, as in products made from diamond turning machines and requiring interferometer systems for length realization.
- Ultraprecision, characterized by devices fabricated by atom- and ion-beam machining and requiring scanning tunneling microscopes (STMs) for verification. As might be expected, the tolerances permissible for specific applications are declining [Fig. 2].

Engine blocks are in the normal machining regime. In 1980 the required machining accuracy was 7.5 μm. In the year 2000 it will be 1 μm. Japanese automobile manufacturers require a 7–8-μm tolerance for metal-matrix composite pistons in their new engines—on a par with the precision required for fine watches! The U.S. state of the art in automobile manufacturing requires only 12-μm tolerance for transmission housings, clutch covers, engine blocks, and cylinder heads. Even though these tolerances are not as exacting as those applied in the Japanese industry, the coordinate-measuring-machine requirements for the automotive manufacturing industry are already pushing NIST's capabilities.

Coordinate measuring machines (CMMs) are a definite weakness in U.S. industrial metrology. These robot-like machines have an arm with three axes of movement, each axis being governed by an interferometer for high linear accuracy. This accuracy is maintained through regular calibrations with step gages, which are pieces of metal with a precisely machined step, or notch. As manufacturing processes demand ever higher precision, CMMs are becoming a more familiar presence on the shop floor.

At Caterpillar Inc. in Peoria, Ill., for example, a recent modernization of the manufacturing plant included greater use of CMMs on the factory floor for verifying design requirements. So the company was disconcerted to find that "obtaining length standards of adequate accuracy, certified by NIST, for use in certification and ongoing verification of our new CMMs, is a problem of ongoing concern," according to B. P. Sorel, a vice president of the company.

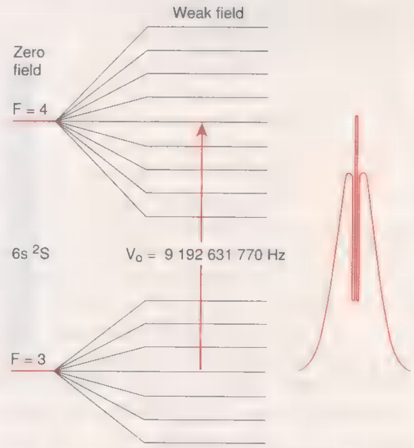
Sorel said that Caterpillar was forced to use step gages certified by the PTB, the German standards bureau. Like their counterparts in other countries, U.S. executives prefer not to rely on nondomestic organizations for critical metrological certifications. The reasons for this preference are not surprising, and include the greater convenience and, oftentimes, more favorable economics of using domestic services, as well as fear of becoming dependent on a source over which the company has no control and against which it has little recourse if problems arise.

In a letter to NIST about the step gages, the Caterpillar vice president wrote that "the current situation is unacceptable...We cannot afford the cost and time of continuing to send reference artifacts to Europe for certification."

Likewise, there are unmet needs for reference measurements in the ultraprecision regime, notably in support of the development of new technology. Of particular concern is metrological support for the various competing lithographic techniques (ultraviolet, X-ray, and electron-beam) being improved or developed for the fabrication of future ultradense ICs.

In general, adequate metrological support for IC fabrication requires dimensional measurement errors less than one fourth of the specification being measured—line width, for example. However, "our current capabilities are marginal with respect to this standard and we are severely limited in our ability to develop 0.25 μm technology," according to a recent report from the Photomask Division of E. I. du Pont de Nemours & Co. in Wilmington, Del.

While the scanning tunneling microscope (STM) is widely known as an imaging system, it can also be used to produce nanometer-scale structures. The same probe tip that produces high-resolution spatial imaging of molecular-scale structures can dou-



[3] The most accurate determinations of time typically employ a cesium clock. The atoms of cesium have one electron in their outer shell, and the possible energy levels this electron can occupy multiply in the presence of a weak magnetic field. For example, the levels labeled F=3 and F=4 split up into seven and nine sublevels, respectively. The arrow indicates the energy-level transition used in the operation of the cesium clock and caused by the absorption of a very narrow, spike-shaped spectrum of microwave energy. The spectrum peaks at v_o, a frequency known to great precision and exploited for the highly accurate time measurements.

ble as a tool for nanofabrication. Perhaps the best-known demonstration of this capability was the infinitesimal "IBM" logo created at the company's Yorktown Heights, N.Y., research laboratory a year ago.

The IBM demonstration was basically publicity for its high technology, but some researchers have great faith that nanofabrication will lead to many useful new products, such as better and cheaper solar cells, advanced materials, medical treatments, and soil- and water-cleansing agents. NIST, for example, has already experimented with an STM probe on hydrogen-passivated materials, producing stable nanometer-scale structures that might be suitable as the basis for extremely dense ICs. Being in the nanometer realm, these devices would be roughly a hundred times smaller than today's IC features.

As a final note on dimensional metrology, it is worth pointing out that NIST periodically compares its measuring capabilities with those of other laboratories. For example, NIST recently performed a comparison between its own meter measurement, based on interferometry, and one of the meter bars, No. 12924, of the Bureau Internationale de Poids et Mesure. The measurement was accurate to within 0.02 part per million of the *mean* of the measurements of other international laboratories.

A U.S. company was forced to use step gages certified by the German standards bureau

TIME AFTER TIME. Time standards may not be as tightly linked to competitiveness as the dimensional and electrical metrics. Nonetheless, temporal metrology has been the subject of intense activity and several advances lately. In its Boulder, Colo., laboratory, NIST can measure time with an accuracy of four parts in 10^{14}—far beyond what everyday applications demand but vital for global positioning using satellites.

Most clocks, especially the very accurate ones, are based on frequency standards. A clock, typically, is little more than a mechanism that counts and accumulates the cycles of a frequency standard, and, usually, displays the result. Even rudimentary clocks built about 335 years ago were based on this principle—their frequency standard was a pendulum. Today, most clocks use a quartz crystal as their frequency base.

The performance of frequency standards is usually described in terms of accuracy, reproducibility, and stability. Accuracy is the degree to which a measured or calculated value conforms to some specified value or definition. Reproducibility is the extent to which there is agreement among a set of independent devices of the same design after adjustment of appropriate parameters in each device. Alternatively, it is the ability to reproduce a previous value. Stability refers to the frequency- or time-domain behavior of a process.

Since 1967, the basic unit of time, the second, has been defined in terms of the quantum mechanical relationship between the frequency of electromagnetic radiation and the difference between energy states of an atom. Specifically, one second is defined as "the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom."

Cesium is chosen because its electronic structure is relatively simple, consisting of a single unpaired electron in its outermost shell (6s). The hyperfine energy levels associated with this single outer electron arise from its coupling with the nuclear magnetic moment [Fig. 3]. This structure is used to lock the frequency of a microwave oscillator. Other reasons for using the cesium atom to define the second include the convenience of the microwave frequency of the transition, the relative insensitivity of the chosen transition to the magnetic field, and the low value of the cesium melting point, making it easy to create a beam of cesium atoms at temperatures below 100°C.

This approach has been improved over the years, to the point where current methods use an optical pumping scheme for selecting a particular pair of hyperfine energy levels. Laser-pumping all of the atoms into the proper atomic state has a number of advantages. It greatly enhances the output signal-to-noise performance, since the older state-selection techniques based on separation in a magnetic field threw away 15/16 of the atoms fleeing the cesium oven. It also obviates the transverse dispersion problems associated with magnetic deflections that cause the atoms to spread and then refocus as they go through the microwave cavity. Lastly, the spectrum of such optically pumped cesium atoms is highly symmetrical, almost eliminating any effects of line distortion due to neighboring transitions.

In addition, the ultimate accuracy of the method is improved if selected atoms, as they go through the microwave cavity, are interrogated with microwave fields having two different frequencies. This leads to a very narrow peak, or structure, at the center of the absorption [Fig. 3]. Norman Ramsey proposed this structure as part of his work on oscillatory mechanisms and their application to atomic clocks, for which he shared the Nobel Prize in physics in 1989.

Within the next few years, further gains in accuracy may be possible with a new kind of clock based on cooled mercury ions. The mercury ion behaves in much the same way as the cesium atom, except it has a very narrow electronic transition in the optical range. This offers the opportunity for a much more accurate clock, provided that the mercury ions can be cooled to temperatures very close to absolute zero. New techniques have been developed, using the pressure of optical radiation, to cool ions contained by an electromagnetic trap.

Quality in manufacturing is ultimately reflected in the accuracy and precision of the product. The examples presented here show that metrology lies at the frontiers of science and technology—witness the fact that today's standards for voltage and resistance are based on phenomena discovered in 1962 and 1978, respectively. To take a newly discovered phenomenon and raise it to an international standard on such short notice reflects the incredible pace of technology. It indicates that metrology is constantly under pressure to advance the state of its art. Yet despite this critical dependence upon metrology the U.S. investments in the field have remained flat for 15 years.

President Bush's 1992 budget called for doubling the laboratory budget of NIST over five years. This was also the Clinton-Gore campaign position. But unless the science and technology communities begin to work more closely with Congress to articulate the importance and meaning of metrology, budget increases will be unlikely. The upshot will be that U.S. engineers and researchers will cease to be able to measure the quantities necessary to reestablish and maintain their country as a leader of technological industry.

TO PROBE FURTHER. "Challenges to NIST in dimensional metrology: the impact of tightening tolerances in the U.S. discrete-part manufacturing industry" (National Institute of Standards and Technology internal report 4757) is available from the National Technical Information Service in Springfield, Va. "Frequency standards and clocks: a tutorial introduction" (National Bureau of Standards technical note 616) is available from NIST's Time and Frequency Division, Boulder, Colo., or the Government Printing Office, Washington, D.C. 20402.

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Designing with superconductors

Superconducting microwave ICs can usefully outperform far larger devices, despite the cost of cooling them to liquid nitrogen temperatures

Microwave and RF designers have always had to pay for high performance—in size as well as cost. For low loss, or high Q, they had to use fairly large and expensive waveguide or coaxial components. Only when specifications were relaxed could a designer benefit from the small size and easy manufacturability of thin-film hybrid microwave ICs.

This dilemma is partly resolved by recent advances in high-temperature superconductors. With their help it is possible to build planar microwave ICs to specifications that actually exceed those of their waveguide and coaxial counterparts. Higher costs are associated with the superconducting circuitry, but the combination of high performance and small size is expected to offset the expense, at least for some applications.

Until 1987, the only superconductors known operated at temperatures so close to absolute zero that they had to be cooled with liquid helium—an expensive and hard-to-handle refrigerant. Liquid nitrogen is far cheaper and easier to handle, but boils at 77 K. Hence the rejoicing early in 1987, when superconductivity above 77 K was discovered in a copper-oxide-based material with the formula $YBa_2Cu_3O_{7-x}$, in which the x is an imprecise small number less than 0.1. This material, and others found since, promise to make superconducting circuitry practical.

Of course, as with any revolutionary change in the rules of a discipline, a careful look at the fundamental assumptions of microwave circuitry should precede the application of superconductor technology to the field. For example, the design rules and circuit topologies that have evolved for such standard microwave IC topologies as microstrip and stripline have passed over some loss mechanisms as trivial compared with losses due to the conductors. Conversely, when superconductors are used, these other loss mechanisms come to dominate the circuit performance.

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George L. Matthaei University of California, Santa Barbara

Also, superconductors behave differently at microwave frequencies than they do at dc. In particular, whereas they are completely lossless at dc, they do have finite losses at RF. The losses are extremely small, but they are not zero.

Basing microwave IC designs on high-temperature superconductors (HTSs), therefore, requires a new generation of design approaches. New criteria for selecting substrate and film materials must be learned, new computer-aided design (CAD) tools must be devised or old ones must be augmented to handle HTSs, packaging techniques suitable for housing cryogenically cooled systems must be developed, and so on. Further, advantage must be taken of the possibility of integrating and cooling whole systems—the superconducting and nonsuperconducting parts—for only in that way will the maximum benefits of HTSs be obtained.

COPPER OXIDES. All the high-temperature superconductors are complex copper-oxide compounds. The most studied is $YBa_2Cu_3O_{7-x}$ (YBCO), which has a critical temperature (T_c) of 90 K. Also widely studied is a family of thallium-containing copper-oxide compounds, which have T_cs as high as 125 K. They, too, are in the forefront of the development of HTS microwave applications. Chief among them is $Tl_2Ba_2CaCu_2O_8$ (TBCCO).

> Thin-film superconductors pack microwave ICs with better performance than waveguide and coaxial assemblies achieve

A third class of HTS materials consists of bismuth-containing copper-oxide compounds, of which the most important is $Bi_2Sr_2CaCu_2O_8$ (BSCCO). These materials have T_cs up to 100 K, and are not as far along as YBCO and TBCCO.

In order to support electronic applications, HTS materials must be grown as high-quality thin films, having low defect densities, low RF surface resistances, high critical temperatures, high critical current densities, and so on. The superconducting films are grown as epitaxial layers, several hundred nanometers thick, on single-crystal substrates.

A typical high-quality film today has a critical temperature above 90 K, a critical current density of at least 10^6 A/cm^2, and a surface resistance of less than 0.5 mΩ at 77 K and 10 GHz. Defects are much more difficult to quantify because the category includes both morphological and electrical defects. The former can be seen with a microscope; the latter are difficult to detect without destroying the film under examination. Currently, commercial films are available with no defects larger than 30μm. But rapid progress is being made in reducing defect size, and films with no defects larger than 5 μm are expected to be available in the near future.

The substrate on which the film is grown must closely match the HTS in lattice constant and temperature coefficient; withstand the temperatures encountered in the deposition process; and be chemically stable in the presence of the HTS. Few substrate materials meet those criteria; lanthanum aluminate, magnesium oxide, and sapphire appear to be the best of those commercially available at this time.

YBCO and TBCCO films are in production on 50-mm-diameter, single- and double-sided wafers of lanthanum aluminate and sapphire [see table, p. 39]. Films on 75-mm substrates are just now becoming available, with 100-mm substrates on the horizon.

Circuit structures are fabricated on HTS-coated wafers with a variety of processes, including photolithographic patterning, wet or dry etching, contact deposition, and passivation. For users who lack the equipment and skills to do the job, commercial foundries will fabricate an HTS circuit precisely to specifications [see table, p. 39].

CAD SHORTCOMINGS. One of the problems in designing microwave circuitry using HTS films is the dearth of adequate CAD tools. The properties of HTS films are unlike those of normal metals, and are not properly modeled by existing CAD packages. Then, too, HTS planar films are being ap-

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plied to circuit structures not normally used for high-performance applications, so that the computer models can be deficient and do not always accurately predict performance.

Some of the differences between normal metals and HTS films are in the areas of skin depth; temperature, frequency, and power dependence; and nonlinear behavior. For example, normal metals are characterized by a frequency-dependent skin depth, and HTS films by a parameter, λ, called the London penetration depth; λ is independent of frequency for small-signal applications in the RF and microwave frequency range, but is a strong function of temperature, especially near T_c.

The kinetic inductance of the HTS films is related to λ and adds to the magnetic inductance. In a transmission line, the propagation velocity is a function of the inductance per unit length; the inductance is a function of λ; and λ is a function of temperature, which increases very rapidly as the temperature approaches T_c. It is usually important, therefore, not to operate an HTS film close to its T_c, and to maintain a constant temperature of operation.

The power dependence of HTS thin films is another area of concern. Single-resonator measurements show that the surface resistance is nearly constant as a function of input power for low power levels, but that it increases as the power increases above a certain threshold. Although this power dependence is definitely a function of film quality, it is not clear whether the dependence is an intrinsic property of HTS films. Measurements made on small-signal bandpass filters made out of TBCCO have demonstrated negligible change in performance for power levels up to 0 dBm when operated at 77 K. However, with improvements in film quality and further evolution of filter structure, power-handling levels of tens of watts may be expected in the near future.

Interestingly, although HTS films generate intermodulation products when more than one signal is present, they do not behave like normal nonlinear devices. Measurements made by various researchers have not shown the expected 3:1 slopes for 3rd-order intermodulation products. Rather, they have shown slopes close to 2:1 in some regions. In any event, for small signals (up to 0 dBm), the resulting spurious responses are usually more than 50 dB down—low enough for most applications.

To handle these various deviations from normal behavior, design tools intended for circuits made from normal metals must be augmented—a job the user must do since no augmentations are yet on sale.

FILTER FORTE. HTS techniques are admirably suited to building small, high-Q bandpass or bandstop filters. Such filters may

Defining terms

Coplanar waveguide: a transmission-line geometry in which a conductor pattern is located in the gap between two ground patterns—all in one plane on a substrate surface.

Critical current density (J_c): the maximum current density a film can carry with zero resistance at a specified temperature.

Critical temperature (T_c): the temperature above which a material ceases to act as a superconductor.

Dispersion: a transmission-line phenomenon in which the various frequency components of a signal travel at different speeds.

Heat lift: the heat transfer capacity of a cooler, expressed in watts.

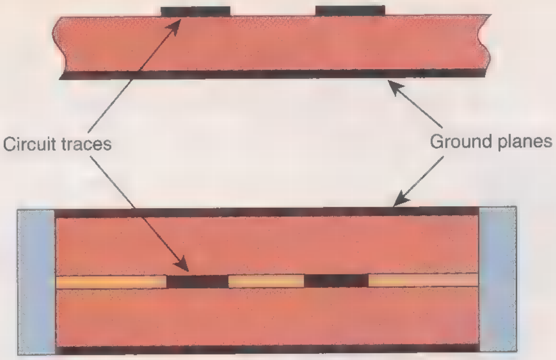
Laser ablation: a method for depositing thin films in which a laser is used to vaporize a material, which then condenses onto a substrate.

Lattice constant: the dimensions of the smallest cell that, by periodic repetition, can be used to represent a crystal structure.

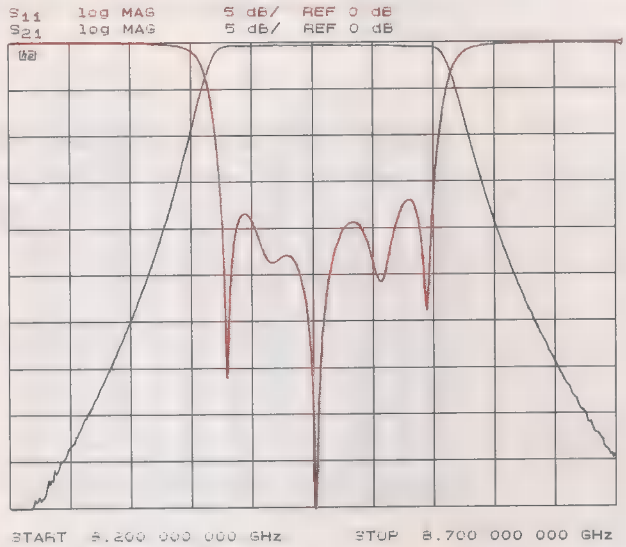
Microstrip: a transmission-line geometry with a single conductor trace on one side of a dielectric substrate and a ground plane on the other side.

Phase noise: the random phase variations of an oscillator—a measure of its short-term stability.

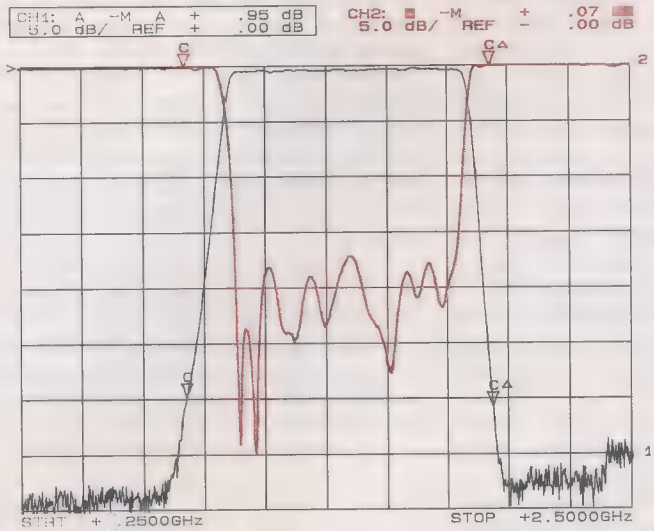
Stripline: a transmission-line geometry in which a single circuit trace is located in the dielectric material between two parallel ground planes.



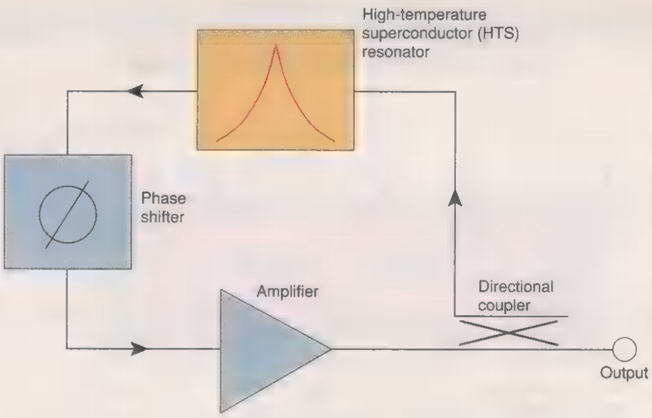
[1] A pair of coupled transmission lines is shown in microstrip form [top] and stripline form [bottom]. In both of these cases, the transmission lines extend into and out of the page. The circuit traces are separated from the ground planes by a dielectric substrate.



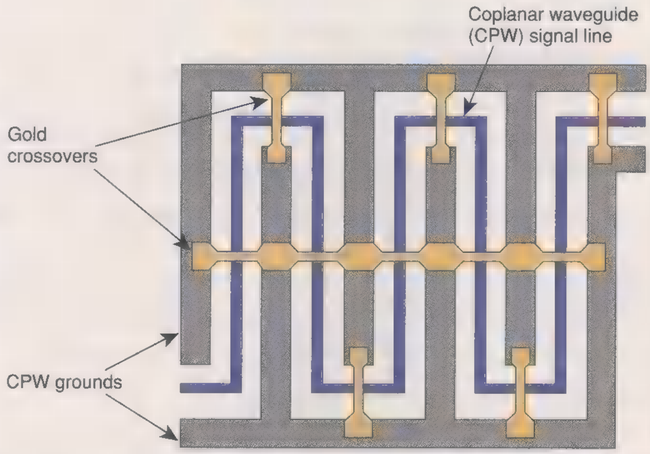
[2] The insertion loss [black] and return loss [red] of a five-resonator capacitive-gap-coupled stripline filter show what high-temperature superconducting (HTS) can accomplish. The horizontal scale is 50 MHz per division; the vertical is 5 dB per division.



[3] The insertion loss [black] of this 9th-order lumped-element bandpass filter is less than 0.2 dB, including connectors. The return loss [red] is better than 17 dB across the passband. Note the excellent selectivity: the 0.5-dB bandwidth is 0.84 GHz, yet the 30-dB bandwidth is only 1.128 GHz.



[4] The HTS resonator is the key component for determining phase noise in this parallel feedback microwave oscillator. Resonator Qs as high as 10^6 have been achieved.



[5] This HTS coplanar waveguide (CPW) delay line exhibited insertion losses of less than 0.1 dB/ns at 6 GHz. The gold straps maintain the ground impedance across the wafer.

call for ■ sizable number of very small, interconnected high-Q resonators—and implementing high-Q resonators is precisely the kind of task at which HTS technology shines.

Microstrip transmission-line techniques [Fig. 1, top] are helpful in implementing high-Q filters because the structures are planar and can be fabricated with standard photolithographic techniques. It turns out, however, that building the circuitry so as to exploit HTS conductors to the full is a tricky business. The reason is that microstrip circuitry, being open at its top, tends to radiate power, and also to lose some energy into so-called surface waves, which are bound to the dielectric.

These losses are of little import in most conventional microstrip designs, where conductor losses dominate. When HTS conductors are used, though, their losses are much slighter than the radiation and surface-wave losses, which must be dealt with if the advantages of the HTS conductors are to be realized.

To quantify the issue, coupled resonators of the type shown in Fig. 1 typically have Qs on the order of 200 in conventional microstrip. If HTS conductors replace the conventional ones, the observed Qs may be somewhere between 1000 and 2000, depending on the various parameters. However, if the loss into radiation and surface waves is suppressed, Qs on the order of 18 000 can be achieved.

The loss from coupled microstrip bandpass filters is due mainly to radiation from the fringing electric fields at the ends of the resonators. Hence, such end-fringing fields should be avoided. For similar reasons, capacitive gaps should be avoided. D.F. Williams and S.E. Schwarz have demonstrated that substituting interdigitated gaps for plain capacitive coupling gaps in coplanar waveguide greatly diminishes their radiation. The same has been found to be true for microstrip.

As always, keeping the substrate fairly thin helps to reduce radiation. HTS microstrip ring-resonator configurations built with interdigitated capacitive-gap loading have exhibited unloaded Qs of 3000 to 5000 (depending upon packaging) at 10 GHz. This was done with a TBCCO film on a lanthanum aluminate substrate.

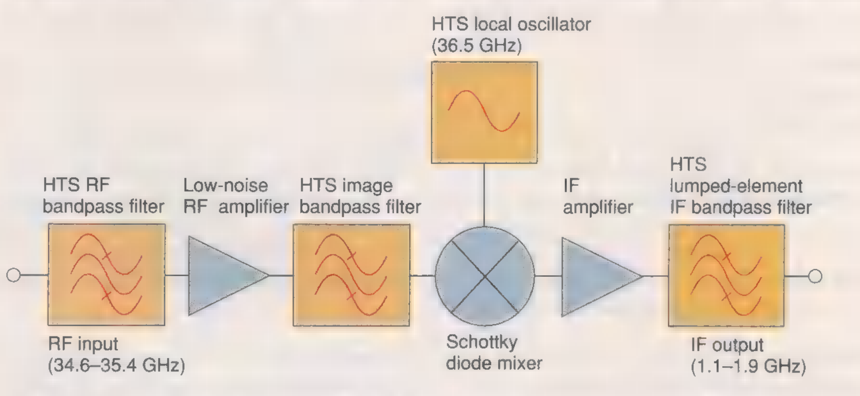
Another way of avoiding radiation and surface-wave losses is to enclose a structure completely. Stripline structures provide a means for doing this while still letting planar technology be used to fabricate the circuit [Fig. 1, bottom]. Since any vertical asymmetry in the stripline structure could couple to a waveguide-type mode bounded by the ground planes and the sidewalls, it is important to design the structure so the waveguide-type modes will be cut off within the frequency range of interest.

The authors have designed and constructed ■ five-resonator, capacitive-gap-coupled stripline filter similar to one described by F.J. Winter and J.J. Taub. Since this structure has ■ top ground plane, capacitive-gap coupling causes no radiation. It, again, uses a $LaAlO_3$ dielectric and a TBCCO HTS.

The impedance level within the filter structure was held to 18.6 Ω, compared with the usual 50 Ω, to help maximize the resonator Qs. This filter, which had a fractional bandwidth of about 1.8 percent, exhibited a total minimum passband loss of about 0.3 dB [Fig. 2]. About 0.15 dB of that loss is believed to have been due to the connectors, which were made of nonsuperconducting metal. Measuring very small passband loss in ■ cryogenic environment is quite difficult to do accurately, so it is hard to say for sure what unloaded Q was realized by the resonators in this filter. However, estimations based on STI measured data suggest that the unloaded Qs were on the order of 10 000.

LUMPED-ELEMENT FILTERS. The performance of lumped-element filters is usually limited by the ohmic loss of the inductive elements. The use of planar HTS circuitry to construct them, however, can reduce the losses so much that high-Q lumped-element filters may be made up to very high frequencies. Through accurate computer modeling and monolithic HTS component fabrication, filters have been built that require no tuning, are tiny, and have excellent performance.

Lumped-element filters with a narrow bandwidth centered at 10 GHz and about 2.5 dB center band loss have been fabricated



[6] By combining HTS and conventional components in one package, and cooling the entire assembly, the designers of this 35-GHz down converter maximize the benefits derived from the cryogenic cooler.

with HTS films. The high Qs of the HTS elements endow this kind of filter with the smallest bandwidths and highest frequencies they have ever achieved. Lumped-element filters outdo distributed filters in size and spurious-free rejection characteristics.

High-order lumped-element filters have also been constructed at lower frequencies, with excellent results. For example, the authors have built a lumped-element, equal-ripple, Chebyshev bandpass filter with a passband that extends from 1.1 to 1.9 GHz [Fig. 3]. The 9th-order filter occupies a substrate measuring 6.0 by 14.9 by 0.5 mm. It is highly selective, with a 30-dB bandwidth of 1.128 GHz compared with a 0.5-dB bandwidth of 0.84 GHz. It has less than 0.2 dB minimum passband insertion loss (including connectors) and better than 17 dB return loss. It also has spurious-free rejection characteristics up to 5 GHz.

STABLE OSCILLATORS. For most applications, a microwave oscillator's key parameter is its stability, which is usually expressed in terms of its phase noise. Since resonators with very high Qs can stabilize such circuits, microwave oscillators are an obvious application area for HTS.

HTS resonators are suitable for both series and parallel stabilized oscillators, but they work best in the parallel configuration [Fig. 4]. The HTS resonator is a key component in keeping the phase noise of the oscillator to a minimum. Using HTS films, resonators have been constructed using microstrip, stripline, coplanar waveguide (CPW), and hybrid combinations of dielectric resonators with HTS ground planes. Qs in the range of 10^5 to 10^6 have been obtained at 10 GHz from a hybrid combination of sapphire pucks with HTS ground planes. Completely planar resonator circuits (microstrip or CPW) at 10 GHz have demonstrated Qs in the 10^4 range.

Antennas are a perhaps unexpected target for HTS, but the technology is hard to beat when small devices are needed. At frequencies below about 1 GHz, the elements of a compact antenna are much tinier than a wavelength, and exhibit radiation resistances of only a few milliohms. Hence, any ohmic losses in the antenna and/or impedance-matching structure degrade antenna efficiency significantly. But when these electrically small antennas and matching structures are constructed from HTS, improvements in efficiency of about an order of magnitude can be obtained.

At millimeter-wave frequencies, microstrip patch antennas made with HTS materials have had much higher efficiencies than others made from normal conductors. One 64-element HTS microstrip patch antenna built on a 50-mm lanthanum aluminate wafer, for example, was 5 dB more efficient than the same antenna made of gold and operated at room temperature.

Another home for HTS thin films is in planar delay lines. When very long transmission lines are constructed with HTS films, long delays can be achieved with low loss in a very small space. Generally, delay lines rely on coaxial cable or waveguide, but at microwave frequencies, they are either very bulky or fairly lossy. Applications using microwave delay lines include signal storage for electronic warfare and intelligence purposes.

When delay lines are employed in conjunction with microwave receivers for some electronic warfare applications, an incoming signal can be delayed long enough to be identified and handed off in its entirety. Such a system could be implemented directly at RF frequencies, thereby ensuring that all signals within a prescribed band were intercepted. Delays on the order of 100 ns would be needed for such a system, with minimum insertion loss and low dispersion characteristics.

> Losses once viewed as trivial—like radiated energy—loom large in the virtual absence of conductor losses

A good transmission line candidate for an HTS delay line is coplanar waveguide. It has low dispersion, and because its ground planes are very near the center conductor, it provides excellent shielding for the transmission lines. To obtain worthwhile delay, a very narrow center conductor line must be used. Typically, these center lines are about 0.04 mm wide, and would cause far too much insertion loss if fabricated out of ordinary metals.

The authors have built superconducting coplanar waveguide delay lines with delays as long as 29 ns and are working toward a 100-ns unit. The 29-ns delay line had a 2.5-meter center conductor, which was fitted on a 30-by-30-mm lanthanum aluminate substrate by forming it in a meander pattern along with the ground planes. The 29-ns delay is equivalent to a 6-meter Teflon cable.

The ground planes were interconnected with dielectrically supported gold crossover straps [Fig. 5]. The straps maintained the ground impedance across the whole wafer. They also shorted out the unwanted even coplanar waveguide propagation mode, which may arise at bends and other discontinuities in the circuit pattern. These crossovers are attached to the HTS circuit through gold ohmic contacts deposited on to the HTS film.

TUNING. Because of inaccuracies in the design process, plus imperfections in the dielectric constant and mechanical tolerances of the substrate, distributed-resonator elements will generally not be tuned exactly as required as they emerge from the photolithographic process. They can be fine-tuned after fabrication either reversibly, with mechanical tuning structures, or irreversibly, by removing conductor material.

Sometimes such static tuning is not enough. Oscillators, for example, may need to be dynamically tunable to maintain a desired level of long-term frequency stability—they may need to be phase- or frequency-locked to a stable reference. In implementing dynamic tuning, it is, of course, essential that the Q of the resonator structure not be degraded. Fortunately, the required tuning ranges are usually quite small, and Q degradation is therefore not often a problem.

Dynamic tuning may also be valuable in the tuning of filter structures. For some applications, both bandpass and bandstop filters could benefit from electronic control of their resonant frequencies. As with oscillators, it is important that the resonator Q not be degraded when tuning is added.

Diodes are often used for high-performance switches in RF and microwave ICs, but their losses are high in the context of superconducting devices. Still, there are other ways to switch HTS circuitry. For instance, the temperature of a narrow section of HTS transmission line can be raised above its critical level, rendering that part of the line nonsuperconducting. This may be done by a number of techniques (embedded heating wires, lasers, and so on) and can yield reasonable on-to-off switching ratios. Unhappily, parasitics are likely to limit the frequency range.

A novel technique developed at STI relies upon overlaying the HTS structures with optically sensitive material and changing the loss state by optically switching the state of the hybrid structure. This process generates large on-to-off ratios, especially for resonant circuits.

DIGITAL INTERCONNECTS. As has long been known, the lower the temperature of silicon MOS logic circuitry, the more rapidly signals propagate through the IC. Consequently, the harder it becomes to raise CMOS speeds by decreasing feature sizes, the more attractive will cryogenic cooling look as a means of boosting performance in high-end workstations, mainframes, and supercomputers.

From using cryogenics to speed up the chips themselves, it is but a small step to employing HTS to shorten delays between chips. It would especially benefit multichip modules, where the low resistance of HTS interconnects can reduce RC time constants and thus speed signal transmission.

Packaging of RF and microwave components and subassemblies is not only crucial to electrical performance, but also to meeting the unique thermal requirements of HTS components. At RF and microwave frequencies, the structure in which circuits

are mounted affects their performance—especially in the case of high-Q resonators. Waveguide modes, cavity resonant modes, and ground inductance are just a few of the many package-related issues. No microwave circuit is complete until it has been mounted in its final configuration and the effect of the housing upon the circuit has been determined.

HTS planar circuits are even more complicated than conventional ones because of the need to handle cryogenic temperatures. For coolers with limited heat-lift capacity, the thermal mass of the circuitry needs to be kept low; otherwise the time required to cool the system down to operating temperature may be unacceptably long.

To reach and maintain the requisite low temperatures while operating the HTS electronics, heat flow into the system from its surroundings must be minimized—usually by mounting the circuitry in a vacuum dewar with a low-emissivity finish and molecular sieve getters. As the vacuum has to be maintained over the intended life of the system, vacuum-compatible materials need to be used.

Conductive heat flow into the cryogenic area is largely through the coaxial cables that connect the HTS circuitry to the environment outside the dewar. Since the usual reason for resorting to HTS circuits at all is to keep loss to a minimum, the cables need to exhibit very low RF losses. At the same time, they must provide a high thermal resistance. Conventional cables have low enough electrical losses, but they also conduct heat very well.

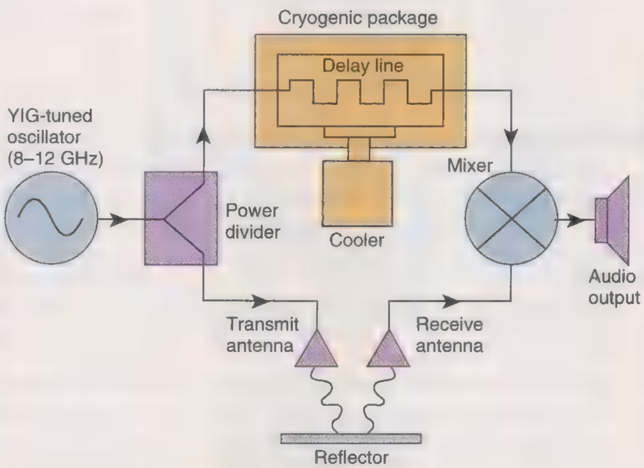
One way to lower the thermal conductivity of the cables is to make the outer conductor extremely thin. A vacuum-compatible cable based on this idea is currently under development at STI.

COOLER QUESTION. As for the cryogenic cooler itself, the big question is whether to use open-cycle or closed-cycle cooling. Open-cycle approaches include cooling with a stored cryogen such as liquid nitrogen or through Joule-Thomson gas expansion. With both of these approaches, the cooling material—be it ■ cryogen or a compressed gas—is used up, usually by release into the atmosphere. Closed-cycle systems, in contrast, do not dissipate material, but they do consume energy, most often electricity.

Being much more highly developed, the open-cycle approaches can boast lower cost and higher reliability. Their drawback is their need for regular replacement of the cryogen or high-pressure gas, both of which call on the user for special handling.

Closed-cycle approaches at least require only electric power, and are potentially low-maintenance techniques. On the other hand, they are about 10 times more expensive than open-cycle methods, and their reliability is high only in fairly large units.

In many industrial, medical, and laboratory environments, open-cycle cooling today suffices for HTS electronic products. But the widespread insertion of HTS circuits hinges on the existence of small, low-cost, and reliable closed-cycle coolers. These units—with a heat-lift rating of several watts, and occupying perhaps a liter of space—are now under development and will arrive on the market within one to two



[7]In this FM continuous-wave radar, the output of the yttrium-iron-garnet–tuned oscillator sweeps linearly from 8 to 12 GHz. When the external path delay equals that of the HTS delay line, the IF output frequency drops to zero, and no tone is generated.

[8] The cooler of this FM continuous-wave radar is mounted on the top left part of the assembly. The cryogenic package containing the HTS delay line is at the rear, behind the antennas.

years. Ultimately, cooler cost will depend on the size of the market, with the prospect that high volumes (more than 100 000 units ■ year) will drive cooler sales price down to a few hundred U.S. dollars each.

IN UNITY, STRENGTH. HTS circuitry will yield the most benefit when combined with cryogenically cooled non-HTS electronics. This kind of assembly would maximize system performance while justifying the extra cost and size of the cooler.

An example of such an integrated assembly is ■ 35-GHz down converter that STI has been developing for high-performance applications [Fig. 6]. The payoff for cooling GaAs high-electron-mobility transistors (HEMTs) operating at 35 GHz is large: the noise figure for the RF amplifier stage comes in at about 1 dB.

Some commerical suppliers of HTS products and services

Suppliers	Uncoated substrates	Coated substrates	Packaging	Coolers	Foundry services
Applied Technology Enterprises (AT&T), Inmo, S.C.; 803-781-6437	$LaAlO_3$				
AKZO International Research GmbH, Ibbenbüren, Germany; (49+5) 459 50181	MgO $SrTiO_3$				
Union Carbide Corp., Crystal Products Group, Washougal, Wash.; 206-835-8566	Sapphire				
Conductus Inc., Sunnyvale, Calif.; 408-737-6700		YBCO films	Yes	No	Yes
E.I. DuPont de Nemours & Co., Wilmington, Del.; 302-695-9320		YBCO and TBCCO films	Some	No	Yes
Superconductor Technologies Inc., Santa Barbara, Calif.; 805-683-7646		YBCO and TBCCO films	Yes	Yes	Yes

HTS = high-temperature superconductor; TBCCO = $Tl_2Ba_2CaCuO_8$; YBCO, pronounced "yibcoe" = $YBa_2Cu_3O_{7-x}$.

The whole assembly is very small, and because of the low noise figure of the RF amplifier and the low-loss planar HTS filters, has ■ noise figure of less than 3 dB.

To demonstrate the practicality of integrated cryogenic assemblies, STI has built an HTS-based FM continuous-wave radar unit using a delay line of the type described earlier. This unit is intended to show that HTS circuitry can be built into ■ cryogenically compatible package and cooled using ■ simple mechanical cooler with no need for liquid nitrogen or any other cooling substance. The unit demonstrates that the thermal problems associated with the HTS delay line have been solved, and a working assembly can be produced.

This radar operates by sweeping a signal from 8 to 12 GHz and then splitting it into two paths [Fig. 7]. One path feeds the signal through the transmit antenna, to a reflective target, and then back to the receive antenna. The other path feeds the signal through the cryogenic package to an HTS delay line, which delays the signal by a fixed amount. The outputs of both paths are then fed to a mixer, which generates the difference frequency between the two signals at the IF port.

For ■ fixed sweep rate from the 8-12 GHz oscillator, the IF frequency is proportional to the difference between the fixed delay in the HTS delay line and the transit time of the signal speeding from transmit to receive antenna via the target. When the reflector is at such a distance from the antennas that the time delays are equal, then the IF frequency from the mixer drops to zero and no tone is generated.

The assembly is driven by electric power only and consumes no material. The cryogenic package that contains the HTS delay line is a vacuum dewar and is located at the rear of the unit, behind the transmit and receive antennas [Fig. 8]. The delay line operates at a temperature of about 80 K.

To sum up, rapid progress is continuing in HTS materials technology and device development. Processes for depositing multilayer, low-defect HTS thin films over large areas are evolving quickly, with commercial availability expected within the next 1 to 2 years. The result should be advanced HTS microwave circuits and HTS interconnect packages for 77 K CMOS computers. In addition, high-quality, manufacturable Josephson-junction devices currently under development will lead to sensitive magnetometers for medical, military, and nondestructive evaluation applications. Over the long term, these devices will also lead to ultrafast HTS logic circuitry.

TO PROBE FURTHER. For an overview of the topic of high-temperature superconductors in microwave circuitry, the authors suggest "Microwave Applications of High-Temperature Superconductivity" by Gregory L. Hey-Shipton, *Wescon Conference Record*, November 1992, pp. 424-427. A progress report on the work of the Consortium for Superconducting Electronics is presented in "Cooperating on superconductivity," by Richard W. Ralston, Marc A. Kastner, William J. Gallagher, and Bertram Batlogg, *IEEE Spectrum*, August 1992, pp. 50-55.

For a discussion of the principal mechanisms through which microstrip circuitry tends to lose energy, see the *IEEE Transactions on Microwave Theory and Techniques*: E.J. Denlinger, "Losses of Microstrip Lines," Vol. MTT-28, pp. 513–522, June 1980; and W.P. Harokopus, L.P.B. Katehi, W.Y. Ali-Ahmad, and G.M. Rebeiz, "Surface Wave Excitation from Open Microstrip Discontinuities," Vol. 39, pp. 1098–1107, July 1991.

The value of interdigitated coupling gaps in reducing radiation is explained in "Design and Performance of Coplanar Waveguide Bandpass Filters," by D.F. Williams and S.E. Schwarz, also in *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-31, pp. 558–566, July 1983. Details on the design of a stripline filter with capacitive-gap coupling are in "High Dielectric Constant Stripline Band Pass Filters," by F.J. Winter and J.J. Taub, as before in *IEEE Transactions on Microwave Theory and Techniques*, Vol. 39, pp. 2182-87, December 1991.

The design of high-frequency HTS lumped-element filters is discussed in D.G. Swanson, R. Forse, and B.J.L. Nilsson, "A 10 GHz Thin Film Lumped Element High Temperature Superconductor Filter," *IEEE MTT-S Symposium Digest*, Albuquerque, June 1992, pp. 1191–3.

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Flexible ac transmission

Tighter control of power flow and increased use of transmission capacity are key benefits of new thyristor-based controllers

The electric utilities' systems for transmitting and distributing power are entering a period of change. Their operation is due to be fine-tuned, to an unprecedented degree, by the application of power electronics, microprocessors and microelectronics in general, and communications. Between them, these technologies will make the transmission and distribution of electricity more reliable, more controllable, and more efficient.

Acting for the U.S. electric utility industry, the Electric Power Research Institute (EPRI) in Palo Alto, Calif., has led the way in this area with several thrusts, not the least being the flexible ac transmission system, known in the industry as FACTS.

The flexible transmission system is akin to high-voltage dc and related thyristor developments, designed to overcome the limitations of the present mechanically controlled ac power transmission systems. By using reliable, high-speed power electronic controllers, the technology offers utilities five opportunities for increased efficiency:

- Greater control of power, so that it flows on the prescribed transmission routes.
- Secure loading (but not overloading) of transmission lines to levels nearer their thermal limits.
- Greater ability to transfer power between controlled areas, so that the generation reserve margin—typically 18 percent—may be reduced to 15 percent or less.
- Prevention of cascading outages by limiting the effects of faults and equipment failure.
- Damping of power system oscillations, which could damage equipment and/or limit usable transmission capacity.

Advantages and savings must be weighed against the cost of the power electronic controllers required. At about US $50–$100 per kilovoltampere (kVA) rating of the thyristor-based controllers, the typical capital cost of these controllers can already be afforded for some utility applications. (Roughly speaking, the cost per kilovoltampere decreases with an increase in the size of the controller.)

The flexible system owes its tighter transmission control to its ability to manage the interrelated parameters that constrain today's systems, including series impedance, shunt impedance, phase angle, and the occurrence of oscillations at various frequencies below the rated frequency. By adding to flexibility in this way, the controllers enable a transmission line to function nearer its thermal rating. For example, a 500-kV line may have a loading limit of 1000–2000 MW for safe operation, but a thermal limit of 3000 MW.

It is often not possible both to overcome these constraints and maintain the required system reliability by conventional mechanical means alone, such as tap changers, phase shifters, and switched capacitors and reactors (inductors). Granted, mechanical controllers are on the whole less expensive, but they increasingly need to be supplemented by rapidly responding power electronics controllers.

The new technology is not a single, high-power electronic controller, but rather a collection of controllers, which can be applied individually or collectively in a specific power system to control the five interrelated functions already mentioned. The thyristor is their basic element, just as the transistor is the basic element for a whole variety of microelectronic circuits. Because all controllers for the flexible transmission system are applications of similar technology, their use will eventually benefit from volume production and further development of high-power electronics.

> A power line can function nearer its top thermal rating if regulated by flexible ac transmission-system controllers

Electric power networks integrate generation and load centers within each utility system and, through interconnections among neighboring systems, share power with vast regional grids. The purpose of this is to take advantage of the diversity of loads, changes in peak demand due to weather and time differences, the availability of different generation reserves in various geographic regions, power-sharing arrangements among utilities, shifts in fuel prices, regulatory changes, and other discrepancies.

TRANSMISSION LINKS. By facilitating bulk power transfers, these interconnected networks help minimize the need to enlarge power plants and enable neighboring utilities and regions to buy and sell power among themselves. Thus, the electric power transmission network is essential for reliable, low-cost power. Conversely, inadequate transmission will result in less reliable, more costly power.

The demands placed on the transmission network have grown in recent years, and will go on growing, both because non-utility generators (NUGs) are entering the market in increasing numbers and because competition among the utilities themselves has heightened. Making matters worse is the extreme difficulty of acquiring new rights-of-way. Although the flexible transmission technology can alleviate some of these pressures, it must be stressed that for much capacity expansion, building or upgrading of lines without resorting to flexible transmission technology will still be the most economical way to go. What is of most interest to the transmission planner are the new options opened up by the technology for controlling power and enhancing the usable capacity of present lines through voltage and current upgrading, impedance modification, and phase angle regulation.

FREE FLOW OF POWER. At present, many transmission facilities confront one or more limiting network parameters plus the inability to direct power flow at will.

A well-known formula states that the power flow between two points along a transmission line is equal to the product of the voltages at these points, times the sine of the difference between their phase angles, all divided by the transmission line's reactance between the two points. To understand the free flow of power, consider

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Two segments—15 Ω and 40 Ω—of the three-phase, series capacitor bank at Kayenta substation of Western Area Power Administration in northwestern Arizona are shown, and the 15- to 60-Ω, 45-MVA thyristor-controlled segment is in metal compartments on the right. Thyristor firing phase angles range from 145 to 180 degrees—a wider range than in previous installations. Built by Munich-based Siemens AG, the installation went on line last October. One of several types of controllers for a flexible ac transmission system, these thyristor-controlled series capacitors allow a tighter control of power, voltage, and series impedance, as well as the damping of oscillations and the enhancement of transient stability, among other attributes.

Defining terms

Phase angle regulator: a controller for shifting the phase angle of an ac voltage.

Static condenser: a solid-state controller, functionally equivalent to a synchronous condenser, which can supply capacitive, as well as inductive, reactive power and may have a small stored energy capability for damping oscillations.

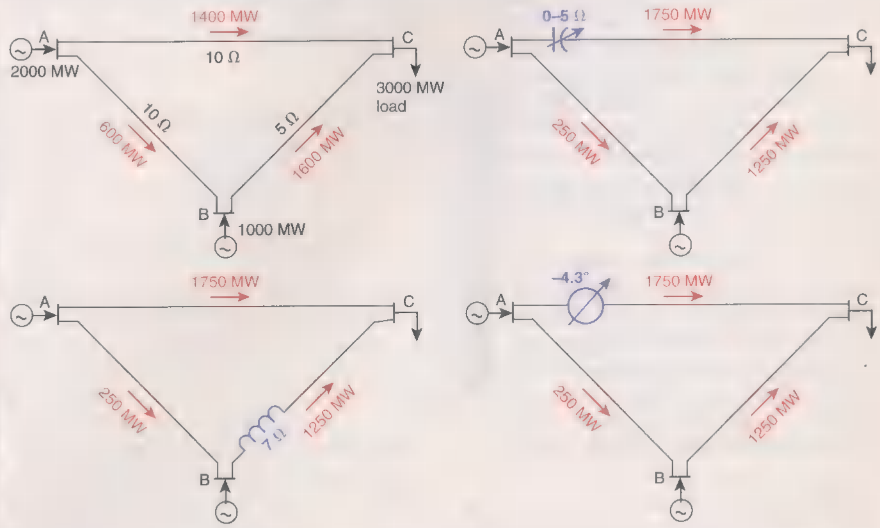
Static var compensator: a solid-state controller that regulates reactive (voltampere) power along a transmission line by switching various combinations of capacitors and inductors in parallel with the line.

SSR damper (in power transmission): a solid-state controller that damps subsynchronous resonance oscillations.

Subsynchronous resonance (SSR): one occurring typically around 15–30 Hz, when a natural frequency of a generator's mechanical shaft coincides with an electrical resonance frequency of the transmission network.

Thermal limit (of a transmission line): the line's maximum current-carrying capacity.

Thyristor valve: a stack of interconnected thyristors used for switching. (Note: the term originates from high-voltage dc converter applications.)



[1] A simple meshed network illustrates hypothetical power flow situations. Here generators at A and B feed a 3000-MW load at C via transmision lines AB, with continuous power rating of 1000 MW, BC (1250 MW) and AC (2000 MW). At the impedances shown, BC will be overloaded, carrying 1600 MW. Series three-phase thyristor-controlled capacitors in line AC [top, right], reactors (inductors) in line BC [bottom, left], or phase shifters in line AC [bottom, right] can restore the flow in BC to no more than its rated 1250 MW.

an elementary case in which two generators are sending power to a load center through a network consisting of three lines in a meshed connection [Fig. 1, top left]. The lines AB, BC, and AC have continuous ratings of 1000 MW, 1250 MW, and 2000 MW, respectively, with emergency ratings of twice those figures. If one generator is rated at 2000 MW and the other at 1000 MW, a total of 3000 MW would be delivered to the load center. For the impedances shown, the three lines should carry 600, 1600, and 1400 MW, respectively. Such a situation would overload one line.

Power, in short, flows in accordance with transmission line impedances that bear no direct relationship to transmission ownership, contracts, or thermal limits. The difference between the free-flow path and the contract path is called "loop flow," and is usually characterized by a circulation of power that leaves the available capacity underutilized.

If, however, a capacitor whose reactance is $-5\ \Omega$ at the synchronous frequency is inserted in one line [Fig. 1, top right], it reduces the line's impedance from $10\ \Omega$ to $5\ \Omega$, so that power flow through the lines will be 250, 1250, and 1750 MW, respectively. It is clear that if the series capacitor is adjustable, then other power-flow levels may be realized in accordance with the ownership, contract, and thermal limitations. This capacitor could be modular and mechanically switched, but the number of operations would be severely limited by wear on the mechanical components.

Other complications may arise. A series capacitor in a line may lead to subsynchronous resonance, typically at 15–30 Hz. This resonance occurs when the mechanical resonance frequency of the shaft of the generator at risk coincides with 60 Hz minus the electrical resonance frequency of the capacitor in series with the total system impedance. If such resonance persists, it soon damages the shaft. Furthermore, while the outage of one line is forcing other lines to operate at their emergency ratings and carry higher loads, power-flow oscillations at low frequency (typically 1–2 Hz) may cause generators to lose synchronism, perhaps prompting the system's collapse.

If the series capacitor is thyristor controlled, however, it can be operated as often as required and can be modulated to rapidly damp any subsynchronous resonance conditions, as well as low-frequency oscillations in power flow, and allow the transmission system to go from one steady state condition to another without damage to a generator shaft or the collapse of the system. In other words, a thyristor-controlled series capacitor can greatly enhance the stability of the network. More often than not, though, it is most practical for part of the series compensation to be mechanically controlled and part thyristor controlled, so as to counter the system constraints at least cost.

Similar results may be obtained by increasing the impedance of one of the lines in the same meshed configuration by inserting a $7\text{-}\Omega$ reactor (inductor) in series with the line [Fig. 1, bottom left]. Again, a series inductor that is partly mechanically and partly thyristor controlled could serve to adjust the steady-state power flows as well as damp unwanted oscillations.

In either case, a thyristor-controlled phase angle regulator could be installed instead of a series capacitor or a series reactor in any of the three lines to serve the same purpose. Note that neither the inductor nor the phase angle regulator contributes to subsynchronous resonance. At lower right in Fig. 1, the regulator is installed in the third line to reduce the total phase angle difference along the line from 8.5 degrees to 4.2 degrees. As before, a combination of mechanical and thyristor control in the phase angle regulator may minimize cost.

Several controllers are presently being evaluated for flexible transmission systems, while others have been conceptualized but not yet developed. What might be called the first generation of controllers includes two thyristor-based systems that have found use in some utility systems for several years.

STATIC VAR COMPENSATOR. The first, a static var compensator (SVC), has been used since the mid-1970s. It addresses the problem of keeping steady-state and dynamic voltages within bounds, and has some ability to control stability, but none to control active power flow. The SVC uses thyristor valves to rapidly add or remove shunt-connected reactors and/or capacitors, often in coordination with mechanically controlled reactors and/or capacitors.

Mechanical controllers need supplementing by rapid-response electronic systems

The first application of an SVC to voltage control was demonstrated on the Tri-State G&T System in 1977 by General Electric Co. (GE), which is headquartered in Fairfield, Conn. Another SVC with voltage and stability control, developed with EPRI funding by Westinghouse Electric Corp. of Pittsburgh began operation in 1978 on the Minnesota Power and Light System [Fig. 2, top]. (Incidentally, since EPRI's launching of the flexible ac transmission system strategy in 1986, the market for SVCs has increased substantially.)

The second controller in actual use is the NGH-SSR Damper, invented by the author to counter subsynchronous resonance (SSR). SSR instabilities are at times an undesirable side effect of using a mechanically controlled series capacitor to add up to 80 percent compensation to a transmission line, the goal being to lower the line's impedance, increase power flow, and expand stability limits. In the early 1970s, after the shaft of a turbine generator belonging to Southern California Edison Co. was damaged by subsynchronous resonance, the series compensation level on a major 500-kV transmission corridor had to be reduced, so that less power could be transferred over it. Since then, various solutions to the problems of sensing subsynchronous resonance, emergency-switching, blocking it, and so on, have been adopted.

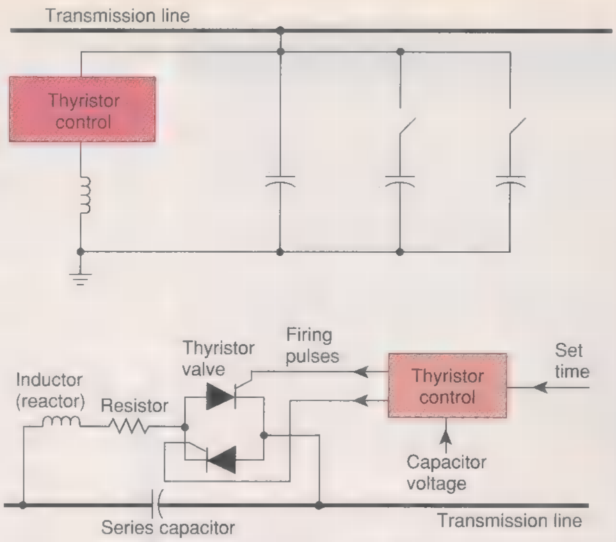
RESONANCE DAMPER. The NGH-SSR damper consists of a thyristor ac switch (back-to-back thyristors) connected in series with a small inductor and resistor across the series capacitor. The operation of the damper is based on two principles. One is to fire the switch 8.33 ms after each zero of the capacitor's voltage, or half a cycle (or 180 degrees) at 60 Hz. But if the voltage wave contains other frequencies, some half cycles will be longer than 8.33 ms. In this case the valve firing at 8.33 ms causes some current to flow during the extended part of the half cycle and damps the oscillations.

The second principle is to fire the switch somewhat earlier than 8.33 ms, or less than 180 degrees following the zero. Earlier firing causes the impedance of the combined circuit to be more negative than that with the capacitor alone, thus detuning the electric circuit. Furthermore, by modulation of the firing angle, the impedance can have a powerful damping effect at any unwanted frequency below the main frequency.

In an SSR damper installed in Southern California Edison's Lugo substation [Fig. 2, bottom], the thyristors have a modest current rating (15 percent of load) for continuously bypassing the capacitor's wave for only up to the last 10 degrees or so of the voltage wave. With more cooling of the thyristors and appropriate sizing of the reactor or resistor in series with the thyristor switch, this damper forms the basis for the fully rated thyristor-controlled series capacitor described later.

With the recognition of flexible ac transmission technology as a highly effective means of enhancing power systems, a second generation of controllers is beginning to emerge. About a dozen thyristor-based systems have been identified as likely to improve the performance of an ac system. Six are being pursued for development as part of EPRI's proposed 10-year collaborative

[2] A static var compensator is at the Minnesota Power and Light System at Shannon substation near Hibbing, Minn. It has three single-phase thyristor-controlled reactors (inductors) capable of delivering a reactive power of 40 Mvar[top]. A thyristor-controlled resistor and reactor, in a scheme developed by the author, help damp subsynchronous resonance oscillations by providing a current path that bypasses the capacitor on the transmission line [bottom].



R&D plan for the technology.

Most vital to power and stability control, obviously, is the ability to control impedance or phase angle. Since the series impedance of a typical transmission line is mostly inductive, with only 5–10 percent resistive, it is convenient to control a power system's steady-state impedance by adding both a thyristor-controlled series capacitor and a thyristor-controlled series reactor (inductor). Since the capacitor is a negative impedance, the introduction of a variable series capacitor means a variable negative impedance in series with the line's natural positive impedance.

THYRISTOR-CONTROLLED SERIES CAPACITOR. Thus the thyristor-controlled series capacitor can vary the impedance continuously to levels below and up to the line's natural impedance. On the other hand, adding a thyristor-controlled series reactor means adding a variable positive impedance to a value above the line's natural positive impedance. Once installed, either will respond rapidly to control signals to increase or decrease the capacitance or inductance, thereby damping those dominant oscillation frequencies that would otherwise breed instabilities or unacceptable dynamic conditions during and after a disturbance.

The first of the new controllers to be demonstrated on a utility transmission system is the thyristor-controlled series capacitor (TCSC). In 1991, American Electric Power Co. of Columbus, Ohio, began testing a prototype switch on one phase of the series capacitor bank at its 345-kV Kanawha River Substation in West Virginia. The switch was supplied by Asea Brown Boveri, Vasteras, Sweden. Although the switch is not strictly speaking a thyristor-controlled series capacitor and the test installation is only single phase, the rapid switching of capacitor segments in and out of the circuit do test the key hardware. In some applications, the thyristor-based switching is justifiable for its reliability and speed.

In October 1992, the Western Area Power Administration (WAPA), Golden, Colo., dedicated the first three-phase thyristor-controlled series capacitor installation. It was built by Munich-based Siemens AG and installed at the WAPA Kayenta Substation in Arizona in a 300-km, 230-kV, 300-MW transmission line. The installation includes three segments: one 15-Ω, one 40-Ω, and one 55-Ω series capacitor bank. Only the 15-Ω (45-MVA) bank is thyristor controlled. This installation is a pioneering step because the 15-Ω bank can be controlled smoothly and rapidly from 15 Ω to 60 Ω through the controlled firing angle of the thyristor valves—as in the NGH subsynchronous resonance damper, but over a wider range, from 145 degrees to 180 degrees. The installation allows the transmission line capacity to be increased from 300 MW to 400 MW.

The construction of a large three-phase thyristor-controlled series capacitor installation on a 500-kV line is in progress at the Slatt Substation of Bonneville Power Administration (BPA) in Oregon. (This BPA line is connected to Portland General Electric Co.'s Boordman power plant in Oregon.) The installation features the full range of controls and operating requirements.

Developed and designed by GE in Schenectady, N.Y., with EPRI funding, it is due for completion by mid-year. Each of the three phases includes a platform that consists of six identical series-connected capacitor modules, 1.33 Ω each, with a parallel-connected thyristor switch in series with the 0.2-Ω inductor [Fig. 3]. Each module can be controlled smoothly by advancing the firing angle by a few degrees from the 180 degrees of each half wave, as in the NGH-SSR damper. Also, when the thyristor in a capacitor module is fully conducting, the equivalent of a parallel connected −1.33-Ω capacitor and +0.2-Ω inductor gives an impedance of +0.24 Ω. Thus with a combination of a pull bypass and partial conduction of all six modules, the impedance can be controlled approximately from +1.4 Ω to −16 Ω. (The larger value is obtainable with certain firing-angle combinations.)

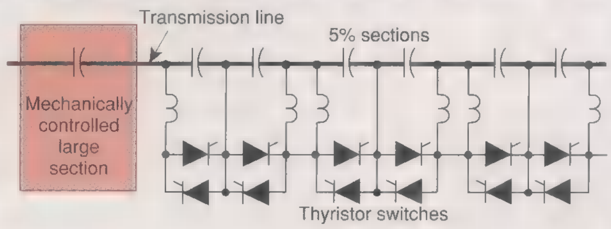
The installation has a rated current of 2900 A, with a short-term overload rating of 4350 A for 30 minutes and 5800 A for 10 seconds and a fault current withstand rating of 20 000 A rms.

Each thyristor switch consists of five thyristors in series, triggered by light signals from the control room. Deionized water passes through insulating hoses to cool the thyristors, maintaining an ambient temperature range of −40 °C to +40 °C.

The thyristor-controlled series capacitor includes remote impedance control, power control, and current control through a Supervisory Control and Data Acquisition (Scada) system. Functional features of the NGH-SSR are included to mitigate the subsynchronous resonance, not to mention power swing damping, transient stability control, assorted local protection features, and overload management. The modularity and high current rating of this installation will confirm this technology's usefulness for a whole range of requirements.

The Bonneville Power Administration is also studying the application of the thyristor-controlled series capacitor to specific ac interties, namely, for transmission lines crossing the Cascade Mountains to the areas around Puget Sound and Seattle, Wash., and around Portland, Ore., and also to the Western Montana Transmission system. All have potential for the enhancement of usable thermal capacity.

STATIC CONDENSER. As mentioned earlier, the static var compensator that uses thyristor switches is already a firmly established piece of equipment for voltage control. In the years to come, however, it will be outperformed by another concept called the static condenser, or Statcon [Fig. 4, top left]. In essence, the Statcon is a three-phase inverter that is driven from the voltage across a dc storage capacitor and whose three output voltages are in phase with the ac system voltages. When the output voltages are higher (or lower) than the ac system voltages, the current flow is



[3] Each phase of the thyristor-controlled series capacitor under construction for the Slatt substation of the Bonneville Power Administration in Oregon has six 1.33-Ω modules, allowing a vernier control.

Flexible ac transmission system controllers

Type	Attributes
NGH-SSR damper	Damping of oscillations, series impedance control, transient stability
Static var compensator (SVC)	Voltage control, var compensation, damping of oscillations
Thyristor-controlled series capacitor	Power control, voltage control, series impedance control, damping of oscillations, transient stability
Static condenser (Statcon)	Voltage control, var compensation, damping of oscillations, transient stability
Thyristor-controlled phase angle regulator	Power control, phase angle control, damping of oscillations, transient stability
Unified power controller	Power control, voltage control, var compensation, damping of oscillations, transient stability
Thyristor-controlled dynamic brake	Damping of oscillations, transient stability

NGH-SSR = Narain G. Hingorani–subsynchronous resonance; var = voltampere reactive (power).

caused to lead (or lag), and the difference in the voltage amplitudes determines how much current flows. In this manner, reactive power and its polarity can be controlled by controlling the voltage.

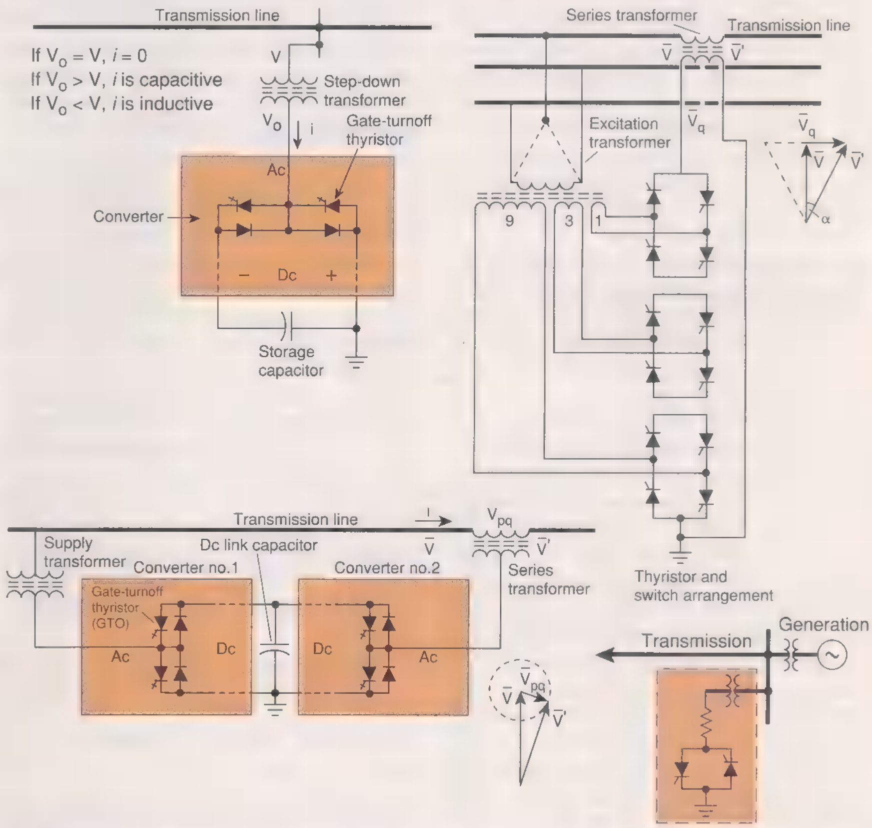
Why the superior performance? The most reactive power that can be delivered from the Statcon equals the voltage times the current, whereas in the case of its predecessor, the SVC, it is the square of the voltage divided by the impedance. Consequently, if the voltage is depressed, the Statcon can still deliver high levels of reactive power by using its overcurrent capability. With the static var compensator, on the other hand, the reactive power capability falls off steeply as a function of the square of the voltage—just when it is needed most. Thus, depending on the application, the rating of the Statcon required will be much smaller than the rating of a comparable static var compensator. In addition, a Statcon equipped with a large dc capacitor or large storage device, such as a battery bank or superconducting storage reactor, can continue to deliver some energy for a short time, just as a synchronous condenser does because of the energy stored in its rotating mass.

However, the Statcon does require gate-turnoff thyristors, which at present cost more than ordinary thyristors yet have higher losses and lower voltage and current ratings. Thus, ordinary thyristor technology has achieved a rating of 8 kV, 4000 A (32-MW peak switching per device), while the gate-turnoff technology has achieved 4.5 kV, 3000 A (13.5-MW peak switching per device). Furthermore, the most promising thyristor concept with gate-turnoff ability is the MOS-controlled thyristor, or MCT, pioneered through EPRI funding. It is already commercialized at low ratings, but has yet to be developed on a scale suitable for utility application.

An experimental 1-Mvar Statcon developed by EPRI with Westinghouse was demonstrated at Orange & Rockland Utilities Inc. in New York State through the sponsorship of Empire State Electric Energy Research Corp., headquartered in New York City. Now, with EPRI and the Tennessee Valley Authority (TVA) as sponsors of Westinghouse, a 100-Mvar Statcon is due to be demonstrated in 1995 at the Knoxville-based TVA's Sullivan Substation. This unit, apart from controlling the voltage, will also be used to damp power oscillations. Without the Statcon, TVA might have had to construct another transmission line.

Another way to control the power flow on the transmission line is the phase angle regulator, as also noted earlier.

PHASE ANGLE REGULATOR. One of a number of different concepts for it is shown in Fig. 4, at top right. The phase shift is accomplished by adding or subtracting a variable voltage component that is perpendicular to the phase voltage of the line. This perpendicular voltage component is obtained from a transformer connected between the other two phases. In the scheme shown, the three secondary windings have voltages proportional to 1: 3: 9. Thyristor switches, one per winding, allow each winding to be included or excluded in the positive or negative direction. The choice of 1, 3, and 9—along with the plus or minus polarity for each winding—yields a switchable voltage range of −13 to +13, thus giving a variable high-speed control of the perpendicular voltage component. The voltage corresponding to each unit step will of course determine the total phase shift that results.



[4] Functionally equivalent to a synchronous condenser, a static condenser (Statcon) is an inverter typically based on gate-turnoff thyristors [top, left]. The inverter supplies capacitive or inductive reactive power depending on whether the storage capacitor's voltage V_0 is larger or smaller than the line's voltage V. A conceptual thyristor-controlled phase angle regulator employs an excitation transformer with three secondary windings with turns ratios 1, 3, and 9; the thyristor switch produces a voltage V_q that is added in series to the line voltage V to produce a phase shift α [top, right].

A unified power controller injects an ac voltage V_{pq} in series with the line voltage V, thereby allowing the control of the phase angle between the resultant line voltage V' and the current i [bottom, left]. A dynamic brake—a thyristor-controlled resistor in parallel with the transmission line—can be used effectively to damp power-swing oscillations in the transmission system [bottom, right].

In another concept of interest, known as the unified power controller [Fig. 4, bottom left], an ac voltage vector generated by a thyristor-based inverter is injected in series with the phase voltage. The driving dc voltage for the inverter is obtained by rectifying the ac to dc from the same transmission line. In such an arrangement, the injected voltage may have any phase angle relationship to the phase voltage. It is therefore possible to obtain a net phase and amplitude voltage change that confers control of both active and reactive power.

EPRI is studying these concepts with WAPA and plans to hold demonstrations of them in the coming years. Generally, the impedance control would cost less and be more effective than the phase angle control, except where the phase angle is very small or very large or varies widely.

OTHER CONTROLLERS. The dynamic brake [Fig. 4, lower right] is a shunt-connected resistive load, controlled by thyristor switches. Such a load can be selectively applied in each pass, half cycle by half cycle, to damp any specific power flow oscillation, so that generating units run less risk of losing synchronism. As a result, more power can be transferred over systems subject to stability constraints.

The dynamic voltage limiter is a shunt-connected, high-power zinc oxide gap-less arrestor controlled by thyristor switches. It can be used to limit overvoltages for hundreds of milliseconds if the transmission line capacity is affected by high dynamic overvoltages.

The thyristor-controlled series reactor resembles the thyristor-controlled series capacitor in that it has a thyristor switch connected across the reactors for swift control of the line's effective inductive impedance.

In all probability, other controllers will be invented. More likely still, numerous improvements will be made in the effectiveness and cost of the basic controllers. The table opposite lists the key controllers along with their attributes.

MAXIMIZING CAPACITY. Long delays and nearly insurmountable problems often hamper or stall the job of securing new rights-of-way or building or rebuilding lines on existing rights-of-way. Yet additional transmission is often required to reduce the need for new generation and also shrink generation reserve margins and improve the fuel economy, all of which are to the benefit of the environment. Utilities have, for a long time, faced the so-called loop flow problem, and now the heavy pressure for access to transmission lines will create many new demands on both line capacity and the ability to control power flow. Hence the timeliness of flexible ac transmission system technology, which can ensure that power flows through the prescribed routes, that the capacity of existing corridors is maximized, and that the secure loading capability is increased under various scenarios of uprating or upgrading the lines' thermal current capacity. EPRI is also investigating transmission line upgrading configurations that will increase transmission capacity as well as decrease the magnitude of magnetic fields.

Flexible ac transmission system technology opens up new utility planning scenarios—putting on the agenda a whole array of options consistent with a new age of competition and environmental considerations. Although this makes the planning process more complex and challenging, planners are responding with excitement and enthusiasm.

> The effectiveness of power and stability control depends on the ability to control impedance or phase angle

It is important, therefore, that planners have the appropriate tools. EPRI funded planning studies by GE and by Power Technologies Inc., Schenectady, N.Y., both of which have enhanced their computer codes to incorporate some flexible ac transmission system controllers. EPRI's own comprehensive code package, Psapac, is continually being updated with more detailed simulations of all the new controllers. These planning tools must continue to be expanded and improved, for only then will the simulation of various controllers be sophisticated enough for planners to consider flexible transmission options routinely and not as an afterthought. There are now eight EPRI member utilities engaged in in-depth planning studies investigating flexible ac transmission systems as an option.

Interestingly enough, for any given case study related to increasing usable transmission capacity and/or control, two planners will most likely come up with different scenarios. That is only to be expected when planning is made more complicated by greatly expanded options.

Much work still needs to be done to firmly establish flexible transmission technology, the most important being the commercial demonstration of various controllers. Their applicability will expand as each new type becomes available. In essence, the controllers are ingenious combinations of advanced but commercially available components, with the thyristor having the most influence on cost.

Another application aspect is the system and engineering cost. Flexible ac transmission applications currently involve considerable customization. As the market grows, however, consolidation of modular designs and marked cost reductions can be expected. A third issue is incentives for new capital investments in the technology, to accommodate new transmission access needs.

Systems engineering as well as hardware aspects are at present being studied by working groups in the IEEE and the International Conference on Large High Voltage Electric Systems (Cigré).

Within the next 20 years, with any luck, electricity should be flowing through controllers between many generating plants and customers, optimizing the use of utility transmission systems.

TO PROBE FURTHER. "Current Activities in Flexible AC Transmission" are discussed in IEEE Publication No. 92TH0465-5-PWR, which came out in April 1992. The *EPRI Journal* for April-May 1986 addresses flexible ac transmission.

"High Power Electronics and Flexible AC Transmission System" was the topic of a speech delivered by the author on April 19, 1988, at the American Power Conference's 50th Annual Meeting in Chicago. It was printed in the IEEE's *Power Engineering Review*, July 1988, pp. 3–4.

The author discusses "Power Electronics in Electric Utilities: Role of Power Electronics in Future Power System" in an invited paper in a "Special Issue on Power Electronics," *Proceedings of the IEEE*, Vol. 76, no. 4, April 1988, pp. 481-2.

N.H. Hingorani and others discuss "Research Coordination for Power Semiconductor Technology" in the *Proceedings of the IEEE*, Vol. 77, no. 9, September 1989, pp. 1376-89.

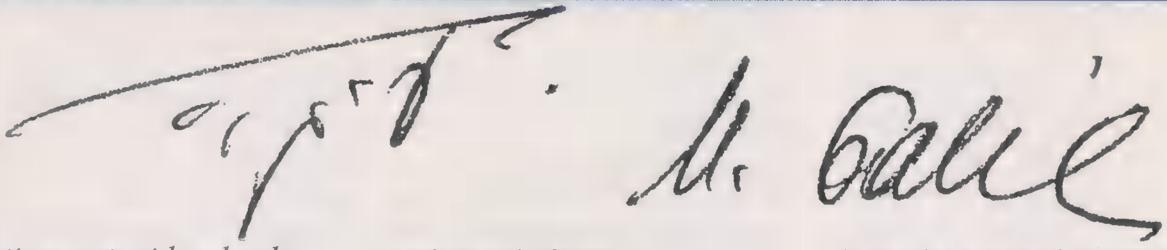
L. Gyugyi, N. Hingorani, and others focus on "Advanced Static VAR Compensator Using Gate Turn-Off Thyristors for Utility Applications," in their paper No. 23-203, prepared for the 1990 session of the International Conference on Large High-Voltage Electric Systems (Cigré), Paris.

Discussions of the flexible ac transmission system appear in the proceedings of workshops held by the Electric Power Research Institute (EPRI) in 1990 in Cincinnati, Ohio, and in 1992 in Boston. Call EPRI Distribution Center at 510-934-4212 and ask for EPRI TR-100504 and TR-101784, respectively.

"Prototype NG Hingorani SSR damping scheme" is discussed in EPRI Report EL-7130, February 1991.

"Case studies of conventional and novel methods of reactive power control on an ac transmisssion system," are discussed in Cigré paper No. 38-02, Paris, 1988.

ABOUT THE AUTHOR. Narain G. Hingorani (F) is vice president of the Electrical Systems Division, at the Electric Power Research Institute (EPRI), Palo Alto, Calif. He is credited with originating the concepts of flexible ac transmission and custom power. ◆



Starting out with a lowly garage operation in the late '50s, Uzia Galil grew to be the main mover of Israel's high-tech industry

Place: a lush, well-kept lawn with a clump of palm trees in its center next to the beach by the Mediterranean. Time: a hot, humid morning in early August. The visitor to a science industrial park in Haifa, Israel, notices a sign by a five-story glass and concrete building at the extreme left of the complex—Elron Electronic Industries Ltd. There can be no mistake—this is the place where many innovative, high-tech ideas of Israeli engineers and scientists make, or fail to make, their first dent in the tough business world of the 1990s. Inside, in a comfortable, spotless, neatly laid-out air-conditioned office, its walls covered with plaques and awards, sits Uzia Galil, the focal point and magnet who has attracted these aspiring innovators.

When his 16-year-old self, Osias Rolling, was anxiously awaiting the train at Bucharest's Central Train Station on March 31, 1941, no such vision of his future could have occurred to him. He was fleeing Romania to get away from the tightening grip of Nazi Germany. A little more than 20 years later, the teenage fugitive would become a major inspiration and a driving force for what eventually would become a thriving electronics industry in Israel.

Today, Uzia Galil (the Hebrew name he adopted in 1952) is chairman of the board and chief executive officer of Elron Electronic Industries Ltd. —a holding company of both Israeli and U.S. high-tech firms with total gross revenues of about US $600 million a year.

As Elron's top executive, Galil works as vigorously as ever to establish and support new companies with promising innovative products and technologies. Elron's 10 companies cover the gamut of electronics activities, including medical diagnostic imaging, defense electronics, data communications, manufacturing automation, semiconductor products, and software.

Gadi Kaplan Senior Technical Editor

In 1978 Galil was named an IEEE Fellow "for the pioneering contributions to the establishment of a modern electronic industry in Israel." In 1984 he also received the IEEE Centennial Medal for extraordinary achievements.

SHAMELESS WORKAHOLIC. The secret of Galil's success? He is persistent and gets things done. His credo: think, decide, do. He demands quality and commitment from everyone, above all from himself. He admits he is a shameless workaholic.

His persistence has brought him prominence. On several occasions he has had contacts with state leaders, including many in Israel as well as Margaret Thatcher, Gerald Ford, and Anwar Sadat, during Sadat's historic visit to Israel in 1977.

Yet, as *IEEE Spectrum* found, Galil is modest, low-key, friendly, and informal with everyone he meets. He started off his day by greeting a group of business executives from the United States who came to discuss a joint venture in the manufacturing of advanced semiconductor chips.

A couple of hours later, Galil spoke by phone with Shmuel Parag, president of Elscint Ltd., one of Elron's group of companies. When that conversation ended, he briefed Yosef Ami, director and consultant of companies on Elron's board of directors. He told Ami about new investments in Fibronics International Inc., Elron's 30-percent-owned affiliate, headquartered in Hyannis, Mass. Fibronics has major operations in Israel and specializes in network solutions, including intelligent hubs and optical-fiber data communications. The work at Fibronics is "very, very special because [the company] is operating in one of the fastest-growing markets worldwide," Galil noted.

Later, Galil called in Zahava Tavor, Elron's chief financial officer, to discuss the figures for the approaching end of the year's third quarter. "Tomorrow we close the books," he said. A brief consultation ensued about a letter Tavor was drafting to the Bank of Israel concerning a bond issue. "The letter must go out today," he told her. After she had left, Galil asked Adina Kadmon, his secretary, about a series of appointments the next day.

BUILDING FROM SCRATCH. With his busy morning over, Galil and the *Spectrum* reporter settled down for a talk. Galil's greatest accomplishment? "To build a high-tech industry in the country from scratch," he answered, confirming what many IEEE members already knew from the Fellow status the IEEE has conferred on him.

His "biggest satisfaction" was that the Elron group of companies was profitable and growing, and was employing about 5000 "very dedicated and very creative" people. A major source of his pride is the latest sales figure of the thriving electronics industry in Israel—gross sales of US $4 billion in 1992, of which about 63 percent is for export. The gross sales represents a staggering growth—a tripling in the last 10 years.

Galil's present prominence is a far cry from his humble and difficult start. In the late 1950s, in a basement apartment at 12 Lotus Street on Mount Carmel in Haifa, he established a "garage operation." There he and ex-Israeli Navy colleague Benjamin Sandler, along with Gideon Kirschner, a specialist in medical electronics equipment and later a cofounder of Elron, serviced ailing

Vital statistics

Name: Uzia Galil
Date of birth: April 27, 1925
Place of birth: Bucharest, Romania
Height: 178 cm
Weight: 75 kg
Family: wife, Ella; daughters, Ruth and Daniela; grandchildren, Mor, Nir, Elad, Eyal, and Inbal
Education: B.Sc.EE, 1947, Technion, Israel Institute of Technology, Haifa; M.Sc.EE, 1953, Purdue University, Lafayette, Ind.
First job: night foreman in a chemical plant in Haifa, Israel
Oddest job: bus conductor (as a student)
Most recent book read: *Prince of Tides* by Pat Conroy
Favorite periodicals: *Forbes* magazine
Favorite composer: Wolfgang Amadeus Mozart
Favorite food: Italian
Favorite cities: New York City, Paris
Pet peeves: stupidity and incompetence, along with an inflated ego
Languages spoken: Hebrew, English, French, and Romanian
Management credo: "Think, decide, do"
Memberships and awards: IEEE Fellow, 1978; member, Israel's Association of Engineers and Architects; member of the Information Processing Association of Israel; Honorary Doctorate in Science and Technology from the Technion (1977), Doctor of Philosophy Honoris Causa, Weizmann Institute of Science, Rehovot, Israel (1991); Industry Prize in Israel (1976); Chairman of Knesset's Prize for Quality of Life (1986); IEEE Centennial Medal (1984)

Judy Gurowitz

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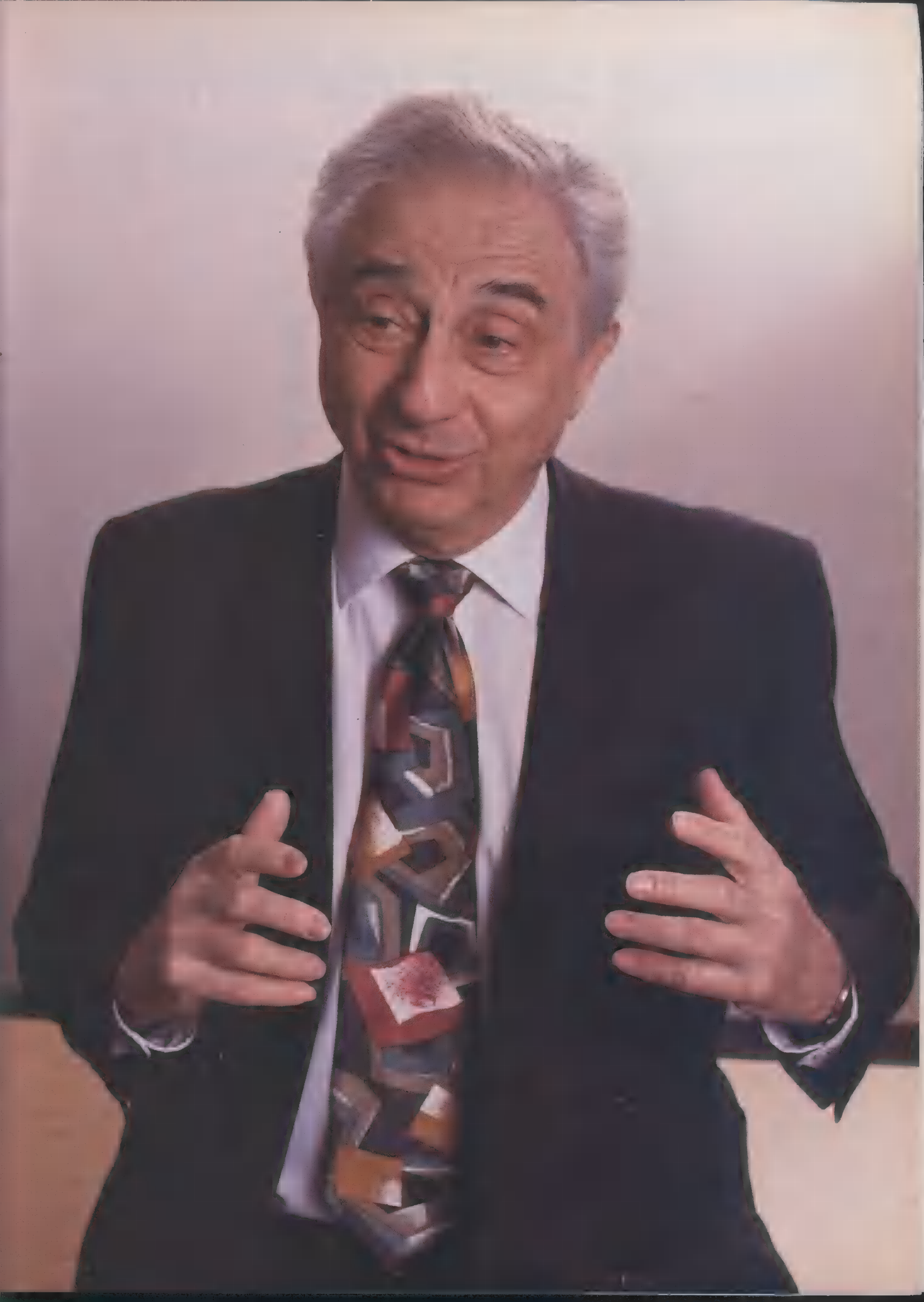

medical and industrial control equipment.

Ideas for new instruments in medicine and physics followed, subsequently bringing about the establishment of Elron Electronic Industries Ltd. in early 1962. It was not a smooth start. In the first weeks of 1962, Galil would constantly worry about meeting the next payroll for the company's eight employees.

But several favorable events happened in early 1962 that would put the fledgling company on a firmer basis. Moshe Arens, then professor of aeronautics at the Technion, Israel Institute of Technology in Haifa (later Israel's ambassador to the United States and its Defense Minister) arranged for a meeting between Galil and Dan Tolkowsky, former Israeli Air Force Commander, who had just joined the Discount Bank Investment Corp. (DBIC). At the same time, the Rockefeller Venture Fund became interested in the company, and, between DBIC and the Rockefeller fund, US $160 000 was invested in Elron—the first venture capital investment in Israeli high technology.

By then, Galil already had a pretty clear concept of where he was headed: harnessing promising scientific and technological R&D to the manufacture of marketable products for industry and defense. The know-how would come from such institutes as the Technion, the Hebrew University in Jerusalem, and the Weizmann Institute of Science in Rehovot. Among the first products were nuclear instrumentation, developed with the Israel Atomic Energy Commission in Tel Aviv, and a fragilligraph, an instrument that measures the fragility of blood cells, developed in collaboration with researchers at Weizmann.

TOUGH CHOICE. But one of the toughest decisions Galil ever had to make was on the horizon: whether to be "completely involved" in R&D, which had been so intellectually rewarding to him, or to abandon his personal involvement in it altogether, in favor of managing the business.

Doing both simultaneously was out of the question. The company had already grown to about 120 employees by 1965, and Galil, while still hand-carrying pay checks to each employee every month, began to find it difficult to remember all the names, let alone memorize their specific technical or other responsibility. "I remember a situation when I started seeing smiles on faces," he recalls. These were forgiving smiles, indicating to him that while the employees were grateful for his attention, they must have felt that he was gradually getting out of touch with the detail of their work. Thus 1965 marked a turning point for Galil. From then on, he has devoted his efforts to management.

In 1966, another important technical and business challenge came up. With Israel's commercial and defense needs growing rapidly, the country had to build its own computer industry literally from scratch. To that end, Galil, along with Alexander Shani, then the head of the computer division in Rafael (the Armament Development Authority of the Ministry of Defense), persuaded Elron's board of directors and the Ministry of Defense to support the establishment of Elbit Computers Ltd. The name melded Elron and *bitachon*—the Hebrew word for security, and the word *bit* from the computer vocabulary. Elbit was to draw on the wealth of skills and innovative ideas within Rafael and Elron.

NAIVE APPROACH. The first product was the Elbit 100, a minicomputer similar to the PDP8 made by Digital Equipment Corp., Maynard, Mass. "It was a very big challenge and [we had] a very naïve approach, and although technologically [the computer was] very advanced, [it] failed because of lack of market understanding," recalled Galil.

> One of the toughest decisions was whether to be 'completely involved in R&D,' or in managing the business

When the Elbit 100 was exhibited in Atlantic City, N.J., in 1968, "we did not understand why people would not buy it," he said. It turned out that the company had been woefully weak in its marketing and advertising efforts.

That was a lesson Galil would never forget. If he had launched that product with what he now knows, he would have beefed up the marketing and prepared enough new software packages for likely users. "It could have become a major, major industry," he believes. Elbit was to flourish later, primarily in defense electronics.

GROWING TOO FAST. The most difficult time in Galil's life came after 20 successful years. The problem surfaced at one of Elron's most prosperous companies, Elscint Ltd., a medical imaging spinoff of Elron's physics and medical division. Established in 1969 with Abraham Suhami, who had just received his Ph.D. in physics from the Technion, the company became a leader in nuclear medicine and a pioneer in computer tomography scanning—the "star of high tech" in Israel.

By 1984 Elscint had exports in excess of $130 million. But within a year, as a result of "too aggressive, major growth" in a very difficult market, accompanied by big, unsuccessful acquisitions of other medical diagnostic imaging companies, Elscint came to the edge of collapse.

The next four years were harrowing. Drastic cuts were necessary, and the company underwent radical restructuring. One thousand employees, or one-third of the workforce, were fired, and new development programs were severely curtailed or shelved.

To Galil and the dedicated people in Elscint, who struggled with him to save the company, this period was understandably agonizing. "He was on the verge of losing Elron to save Elscint," said Benjamin Peled, former commander of the Israeli Air Force and former president and chief executive officer of Elbit, and later, of Elscint.

Nothing could have hurt Galil more than the brutal necessity of laying off all the talent he had been nurturing so devotedly over the years. Indeed, business associates and technical colleagues and protégés, without exception, see him as a man of great integrity and loyalty.

Once Galil identifies a promising technology, or technique, he trusts its creator without reservation. "I am grateful to [him] to this day for his trust and support," said Galil's protégé Shlomo Barak.

In 1981 Barak, who came from military systems work in the ELOP Electrooptical Industries Ltd., Rehovot, convinced Galil that an advanced machine vision system with parallel processing and a smart data acquisition front-end could tackle the new printed-circuit boards, which were becoming so dense that the human eye could no longer inspect them reliably enough.

Today Barak is co-chairman of Orbotech Ltd., a company formed by a recent merger of Orbot Ltd. and Optrotech Ltd., both of which produced machine vision systems for the inspection of printed-circuit boards.

FAMILY TIES. Galil's family plays at least as important a role in his life as his work does. Nothing pleases him more than a family gathering with his wife Ella and his two daughters—Daniela and Ruth—and their families, which include five grandchildren, ages eight to 18.

What about the future? Living in a fast-changing world is the main challenge, Galil believes. "What was right yesterday may not be right today," he told *Spectrum* during his latest visit to Elron's New York City office in late January.

One of the greatest opportunities Galil sees is in high-tech innovation in consumer goods. For example, today Elbit, under the management of Emanuel Gil, is expanding its business into the manufacturing of advanced television sets for export, expecting to be a player in multimedia systems.

Aware of the importance of good investor relations, Galil spends about a week each month in the United States, monitoring Elron's business and maintaining contacts with stockbrokers and analysts.

In spite of traveling more than 330 000 km every month, Galil pretends jet lag does not exist and tries to be active the whole day, although he admits his most creative time is late evening. ◆


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The road to the Deep Space Network

The system that NASA used for communicating with spacecraft exploring the solar system began as a Cold War crash program with foresight

In 1959, Pioneer 4 became the first U.S. spacecraft to escape the earth's gravitational pull and coast toward another body in the solar system: the moon. As the spacecraft passed near the moon, its signals were received by a single 85-foot-diameter* parabolic antenna in California's isolated Mojave Desert. That lone antenna, hastily installed the year before near the Goldstone Dry Lake Bed in the Army's Camp Irwin, became the cornerstone of the Deep Space Network that the National Aeronautical and Space Administration (NASA) would build. Now a system of 13 antennas of various designs and sizes located around the world, the Deep Space Network stays in continuous contact with spacecraft out to the edge of the solar system.

When the Goldstone antenna was procured, however, NASA had not yet come into being. Instead, the antenna's fabrication, erection, and testing in just eight months had been funded by the U.S. Department of Defense. The 1958 crash program, which included a series of five lunar probes, had been approved during the tense months of the Cold War after the launch of Sputnik 1 to speed up the U.S. effort to reach the moon before the USSR.

In all probability, an antenna so hurriedly manufactured and installed for such a short-term goal could have been abandoned when NASA began setting up a permanent system for later lunar and planetary probes. The fact that it was not reflects the careful planning by its designers: a group of engineers at the Jet Propulsion Laboratory, an Army facility in Pasadena, Calif., that ultimately became a part of NASA in late 1958. The early evolution of the Deep Space Network illustrates how, even with limited time and funds, foresight and careful planning can help establish an outstanding system and could even lay the foundation for the system's future growth as resources become available.

Craig B. Waff Jet Propulsion Laboratory

COLD WAR BEGINNINGS. The first official requirement for some kind of system to communicate with space probes was issued on March 27, 1958, when the U.S. Department of Defense's new Advanced Research Projects Agency (ARPA) authorized a program of five attempts to reach the moon within a year. Three attempts were to be made by the Air Force and two by the Army.

Publicly, the administration of President Dwight D. Eisenhower characterized the endeavor (soon named the Pioneer program) as a scientific project—an effort "to determine our capability of exploring space in the vicinity of the moon, to obtain useful data concerning the moon, and provide a close look at the moon."

Archival records are more frank. They show that underlying the program's approval was a desire by many inside and outside the Federal government to restore prestige to the United States in the wake of the USSR's coup: the orbiting of the world's first artificial satellite, Sputnik 1, on Oct. 4, 1957.

In the six months between Sputnik 1 and the announcement of the Pioneer program, aerospace companies and other institutions submitted more than 300 proposals to the Pentagon urging immediate "moon shots" and other space projects. Many cited a perceived Soviet threat.

> After the shock of the Sputnik 1 launch, the United States was urged to 'go to the moon instead of just going into orbit'

One of the first to do so was the Army's Jet Propulsion Laboratory (JPL), which issued its proposal called *Project Red Socks* on Oct. 21, 1957, less than three weeks after the launching of Sputnik 1. In the the proposal's introduction, JPL engineers observed that Sputnik 1 "has had a tremendous impact on people everywhere" and that it "has significance which is both technical and political." They said it was "immediately imperative that the United States regain its stature in the eyes of the world by producing a significant technological advance over the Soviet Union."

The laboratory's director, William H. Pickering, recalled in a 1968 interview that he had pointed out to Government officials and science advisers that the laboratory had "some fairly sophisticated instrumentation and communication" capability that would allow it to support a spacecraft that could fly by the moon. He recommended that the country "go to the moon instead of just going into orbit."

JPL was not alone in sensing that political benefits might flow from a successful lunar mission. Space Technology Laboratories (STL) submitted a competing proposal called *Project Baker* on Jan. 27, 1958. This newly formed division of Ramo-Wooldridge Corp. was headquartered just a few kilometers from JPL in downtown Los Angeles.

STL's game plan argued for an early lunar flight with a moderate payload of scientific instruments that could measure conditions on the moon and so supply invaluable data for planning later flights. But STL noted that "[o]f even greater national importance may be the prestige of sending the first rocket to the moon, with clear proof that it reached its objective."

Some scientists and politicians, however, were only lukewarm about these and other lunar-probe proposals. JPL director Pickering recalled in the 1968 interview that members of the Office of Defense Mobilization's Scientific Advisory Committee (ODMSAC) "were not sure that [the Red Socks proposal] was more of a stunt, as it were, and were not really that enthusiastic about it from a scientific point of view."

Urging caution, too, was Deputy Secretary of Defense Donald A. Quarles, who in a November 1957 speech stated that he found "no cause for national alarm" in the existence of the USSR's Sputnik satellites. Instead, he warned that the United States "must not be talked into 'hitting the moon with a rocket' just to be first, unless by doing so we stand to gain something of real scientific or military significance." And President Eisenhower himself told colleagues on Feb. 4, 1958, that he would not be drawn into a "pathetic race" with the Soviet Union, and he

*While *Spectrum* style usually follows IEEE practice in employing SI or metric units, this article, in order to preserve historical authenticity, adopts wherever appropriate the inch-pound units commonly used by the Jet Propulsion Laboratory and the National Aeronautics and Space Administration at the time.

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characterized a lunar probe as "useless."

That tepidity about "moon shots" changed after the first U.S. attempt to launch a U.S. satellite (Vanguard 1) on Dec. 6, 1957, ended in spectacular failure when the first stage of the launch vehicle exploded within seconds of liftoff—and was broadcast to the world on live television.

On Feb. 17, 1958, the Space Science Panel of Eisenhower's new President's Scientific Advisory Committee (PSAC)—reorganized from the old ODMSAC—held a meeting in the Executive Office Building that set two key objectives. Panel member Herbert York announced to attending representatives from JPL and STL that the committee had decided to attempt a lunar mission to make "contact of some type with the moon as soon as possible," with the stipulation that the contact had to have a significance "such that the public can admire it." York said that the panel had concluded, given the second objective, that "some kind of visual reconnaissance," such as a camera to take a picture of the back of the moon, was the most significant experiment that a lunar vehicle could carry.

PSAC's endorsement of an early lunar mission led Eisenhower the next month to authorize funding for the five Pioneer lunar probes.

SHORT-TERM STL. The Pioneer program required simultaneous development of launch vehicles, spacecraft, and ground support stations. Crucial to the plan were the ground stations, which would transmit commands to the spacecraft, determine their positions and instantaneous velocities, and receive data from them. Without them no close-up photograph of the moon could be received and, more fundamentally, no confirmation that the spacecraft were anywhere near the moon would be possible.

The 60-ft-diameter transmitting antenna at South Point, Hawaii [above], and the 250-ft-diameter radio telescope at Jodrell Bank, England [below], were the two principal antennas used by Ramo-Wooldridge Corp.'s Space Technology Laboratories (STL) for communicating with the Pioneer lunar probes lauched by the U.S. Air Force toward the moon in late 1958.

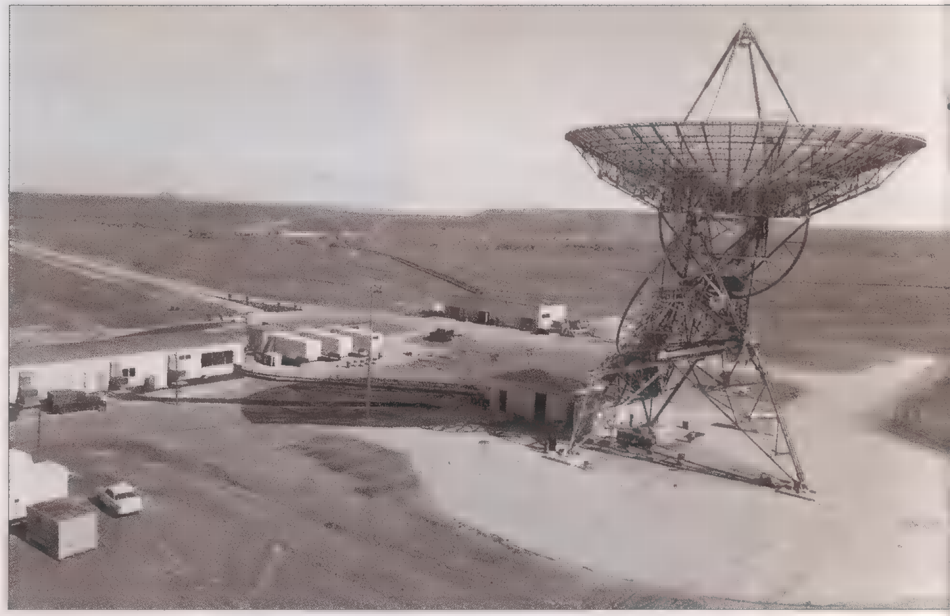
National Aeronautics and Space Administration/Jet Propulsion Laboratory (photographs)

But what kind of network of stations should be set up? Should it be designed solely to support the Pioneer program and its limited objective of photographing the moon? Or should a more elaborate system be constructed, one that would meet not only the requirements of the Pioneer program but also the anticipated needs of future programs not yet authorized—or even yet proposed?

STL, initially under the leadership of Frank Lehan, had little choice but to undertake the short-term approach. Because of the ready availability of the Air Force launch vehicles—Thor intermediate-range ballistic missiles as boosters and Vanguard upper stages—the three Air Force Pioneer probes would be launched first, beginning in mid-August. That early date gave the Air Force and STL the chance to reap the glory of a successful first lunar mission. But it also meant that STL had less than five months to set up a network.

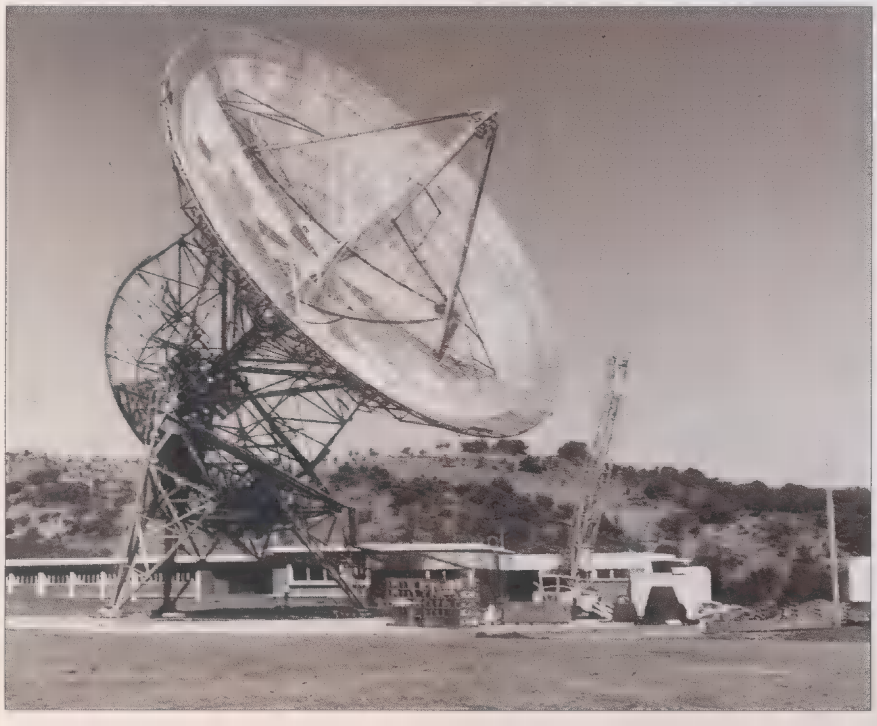
With such a short lead time, Lehan and his colleagues decided that the antennas for the two principal stations had to be already

A single antenna was installed by the Jet Propulsion Laboratory (JPL) in the Goldstone dry lake bed at Camp Irwin, Calif., to support the two Army/JPL Pioneer lunar probes in late 1958 and early 1959 [top]. Later, NASA added two more, one at Woomera, Australia [middle], and the other at Hartebeesthoek, South Africa [bottom], to complete the Deep Space Network. All three 85-ft-diameter antennas were sited so that surrounding terrain minimized outside radio interference. Built by Blaw Knox Inc. of Pittsburgh, they had an identical equatorial design (their main rotational axis was parallel to the earth's) that was cantilevered for strength against high winds. For driving them in hour angle (celestial longitude) and declination (celestial latitude), they all had unusually large gears, which gave them a high pointing accuracy for a relatively low tooth accuracy and minimized the load each tooth would need to bear in a high wind. All operated at 960 MHz, a frequency suited for interference-free interplanetary communications.



either erected or at least manufactured. Their locations would be governed by the roles they would play in communicating with the Pioneer probes in the vicinity of the moon.

One site was to be at South Point on the island of Hawaii. There the antenna would have a favorable "look angle" for taking aim at the probes when the time came to transmit the commands to fire their fourth stage and so insert them into orbit around the moon. At that site, STL decided to install a 60-ft-diameter parabolic antenna with a transmitter; it was a modification of the TLM-18 antenna that Radiation Inc. was currently building for the Air Force Discoverer reconnaissance-satellite program.



STL planned for each probe to begin telemetering photos as soon as it entered lunar orbit, before anything might go wrong with the spacecraft. That milestone was expected to occur when the moon and the spacecraft were passing over the prime meridian (0 degree longitude) on the earth, which crossed parts of Europe and Africa. Lehan and his colleagues knew that the quality of the photos obtained would improve as the diameter of the receiving ground-based antenna was increased. But the five-month time constraint, as well as diplomatic and funding considerations, did not permit the installation overseas of a brand new large antenna.

The University of Manchester, however, had recently built a 250-ft-diameter (76-meter) radio telescope at Jodrell Bank, England. A secret meeting between an Air Force officer and Jodrell Bank's director, Bernard Lovell, enabled STL to fit the telescope with a temporary feed and other spe-

cialized antenna equipment so that it could serve as a ground station for receiving the lunar photos.

Although STL engineers clearly saw the future need for a deep space network, other Ramo-Wooldridge divisions were concerned that if STL undertook the systems engineering and technical direction of the network, it would block the other divisions from participation in building the network's hardware. "We at STL were asked, at that time, to hold back from taking an active part in the program," Lehan recalled. After Lehan and his immediate superior, James Fletcher, left STL in May 1958 to form their own company, George Mueller took Fletcher's place at STL and "did get permission to go ahead," Lehan noted, "but by then it was too late." (Later Fletcher headed NASA and Mueller headed NASA's manned space program.)

It was too late for STL because JPL engineers, by contrast, had begun planning for a permanent network of spacecraft-tracking antennas even before the Eisenhower administration actually authorized money for the Pioneer lunar probes.

JPL'S LONG VIEW. Probably the strongest advocate for a permanent system of ground stations was Eberhardt Rechtin, chief of JPL's guidance research division. More aware than many of his colleagues in the propulsion field of the likely advances in electronics, he knew the interplanetary distances that electronics could enable in space communications [see table, p. 55].

In contrast to others advocating satellites of various kinds orbiting the earth, Rechtin in early 1958 strongly urged the development of a launch vehicle that could deliver a 550-pound (250-kg) payload to the moon and a 300-lb (140-kg) payload to the planet Mars. As he argued in an April 29 telex to an Army Ballistics Missile Agency (ABMA) official, such a vehicle was needed "to accomplish significant missions competitive with the USSR; lesser vehicles will only keep us to the rear in accomplishment of missions." The vehicle, Juno IV (which in the end was never built), would allow engineers to land instruments gently onto the moon's surface, Rechtin pointed out, and could eventually allow the establishment of "quite stable" lunar radio and optical telescopes.

As for Mars, Rechtin argued in two virtually identical technical memos dated May 2, that the planet's often-discussed similarity to the earth would make its photographic exploration "one of the major goals of national prestige between the United States and the USSR." Landing a set of meteorological and surface-condition instruments there could even determine "the practicality of putting people on Mars."

Rechtin predicted that "if conditions on Mars are even slightly more suitable than anticipated, the past success of the human race in new exploration will unquestionably start the drive to Mars. Based on human history, it will then be 'first come–first served' on Mars." Left unsaid, but implied, was the desire that the United States get there before the USSR.

At JPL, Rechtin was not alone in perceiving Mars and the other planets as the ultimate goals of space exploration. Albert Hibbs, who became the first chief of JPL's new space science division, recalled in a 1982 interview that "[W]e wanted a good challenge, and that was *the* technical challenge, getting a useful payload to a planet. It was really tops in engineering challenge—propulsion, guidance, communications, you name it."

It was for this visionary program of lunar and planetary missions that JPL, and more especially Rechtin and his fellow communications engineers, wanted to build a permanent network of stations, capable of transmitting commands to spacecraft, determining their positions and instantaneous velocities relative to the earth or other bodies, and receiving scientific and engineering telemetry data.

In an April 2, 1958, telex to an ABMA official, Rechtin stated: "The design of the stations should be on the basis of a long-term program. This means that the antennas should be precision built rather than simply crudely constructed telemetering antennas." In another telex nine days later, he explained to the same official: "it is much more practical in the long run to set up appropriate stations in the beginning of the space research program. The net cost will be much lower, flexibility of the program will be increased, and all program contractors can be served."

THE IDEAL NETWORK. Rechtin wanted the network to be permanent, meeting both the need to track the apparent motions of space probes and the requirement sure to be imposed by any funding agency: keeping costs to a minimum.

> Nearly seven weeks before Eisenhower authorized the lunar program, JPL engineers began to look for the right antenna design

Rechtin knew that right after a space probe was launched from Cape Canaveral, it would first move rapidly eastward as it escaped the earth's gravitational pull and was injected into its trajectory toward the moon or a planet. Then, as it receded from the earth, its angular velocity across the sky would decrease, until eventually its movement would closely approximate that of any other celestial radio source. During that post-injection phase, the greatest component of the probe's apparent motion would be the rotation of the earth, so the probe would simply seem to rise in the east and set in the west, crossing over each antenna station once a day.

Simple geometry dictates that three is the minimum number of ground stations allowing continuous monitoring because the western horizon of one station overlaps the eastern horizon of the next. Thus, because the world is divided into 360 degrees of longitude, the three stations should ideally be located 120 degrees apart in longitude.

Confident that solar-system exploration would "continue in the coming years," Rechtin and his colleagues sought to design the best possible communication system. He, Walter K. Victor, head of JPL's electronics research section, and Robertson Stevens, head of the guidance techniques research section, wrote about their approach in a 1960 article in the *IRE Transactions on Military Electronics*. There they stressed that "it was important that the basic design be commensurate with the projected state of the art, specifically with respect to parametric and maser amplifiers, increased power and efficiency in space vehicle transmitters, and future attitude-stabilized spacecraft."

Because the launches of the Army/JPL Pioneer lunar probes were scheduled to begin at least three months after the Air Force/STL attempts, JPL had just enough extra time to build its own communication system. And the laboratary determined that its system would be capable of not only monitoring the Pioneer lunar probes, but also of evolving into a permanent support system for future spacecraft exploring the rest of the solar system.

DESIGNING THE DISHES. Rechtin, Victor, and Stevens wanted the antennas to have a pointing accuracy of 2 minutes of arc or better. Because they were to operate 24 hours a day, that accuracy would have to be maintained regardless of any expansion or contraction of the antenna's structure due to exposure to the sun and changes in the ambient temperature.

Moreover, as William Merrick, head of JPL's antenna structures and optics group, and his JPL colleague H.B. Bell later remarked in a memorandum of April 1, 1959, "since missile [launch vehicle] firings cannot be held because the wind is blowing somewhere around the earth nor can the bird [spacecraft] be whistled back from a space mission when the wind comes up," the antenna would have to be usable in winds of 60 miles per hour (about 100 kilometers per hour) and be capable of withstanding (in a stowed position) winds of 120 mph (about 200 km/h).

Rechtin gave Merrick the task of identifying an antenna design that could satisfy such stiff demands. Confident that JPL

would receive a lunar-mission assignment but aware that the procurement, fabrication, and erection of the antennas would be the "longest lead time item," Rechtin boldly assigned Merrick that task on Feb. 7, 1958, nearly seven weeks before Eisenhower authorized the Pioneer program and even 10 days before PSAC's endorsement of an early lunar mission.

Merrick concluded that the desired antenna would have to combine the best features of a precision radio-astronomy antenna and a precision guidance or tracking radar. He and Bell recalled in their 1959 memo that the radio astronomers and suppliers he consulted "questioned our sanity, competence in the field and/or our ability to accomplish the scheduled date [initially November 1958] even on an 'around-the-clock' effort."

Merrick rejected many existing antenna designs because of foreign manufacture (the reasons were not stated), high cost, inadequate aperture, and/or acknowledged design flaws. Other large antennas then being designed—such as the 210-ft-diameter radio telescope for the Commonwealth Scientific and Industrial Research Organization (CSIRO) at Parkes, Australia, and the 140-ft-diameter radio telescope for the National Radio Astronomy Observatory at Green Bank, W. Va.—were eliminated from consideration because they would not be completed until 1960 or later. Merrick outright rejected the Jodrell Bank type of 250-ft-diameter antenna as "too big and expensive." He also pointed out that its design and assembly had required seven years.

Ultimately, Merrick and his colleagues chose a design that had been sketched at the Naval Research Laboratory (NRL) in 1953, developed further by Howard W. Tatel at the Carnegie Institution of Washington, D.C., and refined by the Associated Universities Inc. (AUI); moreover, the design had just been completed by Blaw Knox Inc. in Pittsburgh. The 85-ft-diameter antenna had an equatorial mounting (one whose main rotational axis is parallel to the earth's axis) and this mounting was cantilevered for strength. Its unusually large drive gears for hour-angle (celestial longitude) and declination (celestial latitude) gave a high driving accuracy even though the teeth were not shaped with high precision; moreover, the sheer number of teeth meant that each tooth bore a low load even in high winds.

Blaw Knox, which priced the antenna at about US $250 000, had already received orders from the University of Michigan and AUI for radio telescopes of this design to be built at Ann Arbor and Green Bank, respectively. Neither had been completed in April 1958 when JPL placed its order for three antennas. Citing national priority, the Army was able to move one of the JPL antennas to the front of the manufacturing line.

> 'The design of the stations should be [part] of a long-term program,' stated a telex received April 2, 1958

FINDING A SITE. That first antenna was slated for a site in the United States. Rechtin noted in a memorandum of July 22, 1958, that the planned overseas stations "so rapidly became bogged down in approval red tape" that their activation date gradually moved beyond the second Army lunar-probe attempt scheduled for early 1959.

Although three stations would be essential for any future long-duration flights to the planets, the limited, lunar objective of the Pioneer probes allowed JPL engineers to make do temporarily with one antenna. Continuous around-the-clock monitoring of the probes would be impossible, but JPL engineers deliberately selected a launch time and a trajectory that would cause the probes to arrive at the moon when they were in the line of sight of the single antenna.

Also, unlike their counterparts at STL, the JPL engineers had no need for a separately located transmitter station: the JPL probes were only to fly by the moon, not go into orbit around it, and thus they required no retrorocket firing commands to be sent from a ground station on the earth. In addition, the JPL probes were to start taking pictures automatically when a photocell mechanism indicated that they were within the proper distance from the moon, again eliminating the need for sending special commands.

If subsequent spacecraft were eventually sent to the planets, their received signals would be extremely weak. Thus, JPL communication engineers wanted a site for the first antenna that would minimize outside radio interference. In addition to avoiding areas with power lines, radio stations, radar transmitters, and aircraft passing overhead, they sought a natural bowl-shaped valley, so that the surrounding hills could shield the antenna from nearby towns and vehicles. The soil had to be suitable for accurate and stable support of the antenna, and an access road for the transport of the steel girders and other antenna components would have to be built for such a remote site. Finally, the immediate funding and time constraints of the Pioneer program mandated use of Government-owned land.

Thanks to a search two years earlier for an off-lab site to test rocket engines, JPL engineers were aware of an ideal area near Goldstone Dry Lake at the Army's Camp Irwin in the Mojave Desert about 250 km northeast of Pasadena. One Army general wanted to use the Goldstone area for a missile-firing range, but General John B. Medaris, the head of the Army's Ballistic Missile Agency, overruled him. In May 1958 work began on converting the site into the first Pioneer ground antenna station.

Carefully keeping clear of unexploded ordnance lying in the area, workers built access roads, laid the antenna's foundation, and erected support buildings. Soon after the steel antenna components arrived in mid-August, a crew from the Radio Construction Co. began assembling them. Two months later, the feed was installed and optical and radio-frequency tests were conducted to establish the system's tracking accuracy. The antenna was ready for service in November 1958, about a month before the actual launch of the first Army/JPL lunar probe.

CHOOSING A FREQUENCY. The STL engineers had chosen to operate their Hawaii and Jodrell Bank stations at the 108-MHz frequency that was being used for the Vanguard and Explorer satellites. The JPL engineers decided not to follow suit. With future missions clearly in mind, they noted in a research summary of Aug. 1, 1958, that terrestrial and galactic radio noise below 500 MHz caused so much interference that it would "seriously limit the growth potential of any space communication technique" for interplanetary missions.

At first, Victor favored a frequency between 1365 and 1535 MHz. Because that region bracketed the astronomically important 21-cm line of gaseous hydrogen in space, he expected that JPL's antenna receivers would benefit from hardware developed to improve receiver sensitivities for radio telescopes. His JPL colleagues soon convinced him, though, that a stable, efficient spacecraft transmitter operating in that region could not be built in time for the Pioneer probe missions. So Victor opted instead for an operating frequency of 960 MHz.

The hard work that the STL and JPL communications engineers expended in a few short months on setting up their respective systems of antenna stations paid off with satisfactory operations during the actual missions. Included among the stations were several with smaller antennas at the Cape Canaveral, Fla., launch site and down range from it for coverage of the injection phase.

A string of rocket failures, however, prevented all but the second Army/JPL probe (launched on March 3, 1959) from reaching escape velocity, and that probe (Pioneer 4) passed too far away (37 000 miles or 60 000 km) from the moon to activate the camera system. By then, the USSR's Luna 1, launched on Jan. 2, had already flown within 9300 km of the moon's surface. Luna 3, launched on Oct. 4, 1959—two years after

Table I
Summary of Illustrative Communication System Characteristics for Space Program

Characteristics	1958	1959	1960	Remarks
A. Space-to-Earth Path				
1. Space-to-earth frequency	1,000-2,000mc	1,000-2,000mc	1,000-2,000mc	Maximum S/N ratio: best compromise between tracking accuracy and angle acquisition.
2. Vehicle transmitter power	0.1 watt	1 watt	10 watt	Early [illegible] of solar energy.
3. Vehicle antenna gain	6 db	10 [illegible]	18 db	
4. Ground tracking stations	2	4	4	Three 85' tracking antennas in world net. One 8' tracking antenna at launch site.
5. Ground antenna	85' diam.	85' diam.	85' diam.	Gain at 1,000 mc 46 db
6. Beam width of ground antenna	0.8°	0.8°	0.8°	
7. Angle tracking accuracy	1 - 3 mils	1 - 3 mils	.1 - .3 mils	Use radio stars for calibration and compute for correcting angle data.
8. Ground receiver bandwidth	60 cps	25 cps	10 cps	Using oscillators with increased stability.
9. Ground receiver noise temp.	2000°K	1000°K	400°K	Using low temp. solid state techniques.
10. Ground receiver sensitivity	-148 [illegible]	-155 DBM	-165 DBM	
11. Space-to-earth range for S/N - 10 Db	350,000 mi.	3,500,000 mi.	50,000,000 mi.	
B. Earth-to-Space Path				
1. Earth-to-space frequency	none	1,000 - 2,000mc	1000 - 2000mc	
2. Ground transmitter power	none	10 [illegible]	10 KW	
3. Ground transmitter stations	-	1	2	
4. Ground transmitter antenna	none	85'	85'	Additional 85' dishes required.
5. Doppler velocity	[illegible] way	two way	two way	
6. Range tracking accuracy	-	100 miles	100 miles	
7. Vehicle receiver BW	-	100 cps	100 cps	
8. Vehicle receiver noise temp.	-	30,000°K	3,000°K	
Vehicle receiver sensitivity	-	-134 DBM	-144 DBM	
Earth-to-space range for S/N - 10 Db		10,000,000 mi.	50,000,000 mi.	

Jet Propulsion Laboratory

This table, compiled in April 1958 by engineers at the Jet Propulsion Laboratory (JPL) in Pasadena, Calif., illustrates how [Lines A-11 and B-8] they were even then planning in the long run to send commands and receive data over distances as great as those to Venus and Mars. The National Aeronautics and Space Administration (NASA) did not come into existence until five months later.

Sputnik 1—took the first photographs of the far side of the moon.

The expansion of JPL's ground-support system for the Pioneer lunar probes into a complete three-station worldwide network was not inevitable. The first challenge to JPL's plans came from STL.

YES TO A PERMANENT NETWORK. On June 27, 1958—even before the components of JPL's first antenna were delivered to Goldstone—STL issued a proposal that called for the construction of three 250-ft-diameter antennas near the eastern coast of Brazil, on Hawaii, and in either Singapore or Ceylon.

In the proposal, STL referred to discussions with JPL and "a thorough analysis of foreseeable space programs," including a series of new probes aimed at the planets Venus and Mars that STL was simultaneously proposing. Accordingly, STL suggested that "the long-range interests of the United States in high-altitude communications relay satellites and in interplanetary space programs could best be served by establishing two networks of three stations each, placed at intervals of about 60 degrees around the equator of the earth." The proposal gave no reason why two separate networks were needed, but STL stated that "the estimates given here are believed to be realistic" for completing construction of the first antenna in Hawaii in 16 months—by Oct. 15, 1959.

Rechtin thought otherwise. In a personal communication to the author, Rechtin characterized STL's proposal as "a ploy to block JPL's [network plans] by forcing a study and reconsideration of JPL's ARPA order" for three 85-ft-diameter antennas.

Whether that was true or not, the estimated overall cost of STL's proposed new system was $34 million. How STL expected the Government to approve such a large sum and get the first Jodrell Bank-sized antenna built and operational in so short a time is unclear. The proposal, in any case, was not funded.

A greater threat came early in the next month, when Deputy Secretary of Defense Quarles questioned why STL and JPL were developing two separate systems for supporting the Pioneer lunar probes. In response, Rechtin at once went to Washington, D.C. In [illegible] July 8 meeting at the Pentagon with Richard Cesaro, chairman of an ARPA advisory panel on tracking, Rechtin acknowledged that JPL was using the extra time afforded by the later launch dates of the Army lunar probes "to begin a longer range space tracking program using the proper parameters."

In the July 22, 1958, memo summarizing the meeting with Cesaro, Rechtin noted that those parameters included the 960-MHz operating frequency and a permanent network of the 85-ft-diameter antennas that would be "capable of tracking all vehicles from a 330-mile altitude satellite to space probes to Mars."

Cesaro was won over by Rechtin's presentation. He asked that JPL prepare a formal proposal for [illegible] World Net that would take into account the communications requirements of six intended ARPA space programs: meteorological satellites, reconnaissance satellites, communications satellites (both geosynchronous and low-earth-orbiting), scientific satellites, interplanetary space probes, and manned space flights. It would also handle the detection and track-

ing of "noncooperative" (that is, non-U.S.) satellites.

Two weeks later, on July 25, JPL issued its *Proposal for Interplanetary Tracking Network.* Despite its title, the report considered requirements for those six ARPA space programs. Comparing all the requirements, Rechtin and several colleagues suggested that for several of these programs (including space probes), two antennas could be advantageously placed at Woomera, Australia, and somewhere in Spain. The estimated total cost of JPL's completed three-station network would be under $6 million, less than a fifth of STL's proposal.

Once again, Cesaro was impressed with JPL's work. He told Rechtin that he intended to recommend that "all the tracking and computational facilities should be handled under Army administration with JPL as the technical arm."

Rechtin was delighted with this recommendation, but cautious nonetheless. In an Aug. 6 telex to his JPL colleague Robert Parks, who was temporarily at the Army's Redstone Arsenal in Huntsville, Ala., Rechtin wrote that he believed Cesaro "may be way overoptimistic" in thinking that ARPA had "the power to do this and would put down any rebellion." In particular, Rechtin warned Parks that "we should expect considerable uproar from the Naval Research Laboratory who probably figures it knows more about tracking than anybody else." NRL's Radio Tracking Branch had, under the leadership of John T. Mengel, developed the Minitrack tracking system for the Vanguard satellite program.

Rechtin was wary because Congress had just approved President Eisenhower's request for establishing a civilian space agency, NASA, which was slated to come into being that Oct. 1. NASA's impending formation meant that ARPA was slowly losing its status as the interim U.S. space agency. Furthermore, as time went on, it became clear that both DOD and NASA wanted their own tracking networks, because the defense agency's need for secrecy conflicted with the new space agency's charter for openness.

Even those involved in setting up the satellite and manned-space-flight programs within the new NASA wanted their own networks of ground stations. In particular, as Rechtin had feared, JPL's comprehensive plan was fought by Mengel, whose NRL group was transferred to NASA in late 1958.

Mengel claimed that the installation of more Minitrack stations around the world was more essential for the near-term U.S. space program than the installation of JPL's overseas stations. At a conference of NASA and DOD officials in early January 1959, during which the two agencies crafted an agreement on ground stations, Mengel argued that "the satellite experiments and their associated tracking [were] more important than the deep space effort as far as NASA plans were concerned."

But by this time, NASA had also acquired JPL from the Army. And not everyone in NASA agreed with Mengel. Since early November 1958, NASA had supported JPL's development of recommendations for a set of future lunar and planetary probes. On Jan. 10, 1959, despite Mengel's views, NASA signed an agreement with the DOD that, among other things, called for stations dedicated to the support of deep-space probes to be set up in Australia and in South Africa.

Bound no longer to locate stations at sites that could serve both defense and civilian needs, NASA and JPL now favored South Africa over Spain as the host country for a ground station because most space probes would pass over southern Africa during the injection phase of their flights. Monitoring probes during that phase was crucial for establishing the probes' actual trajectories so that the other antennas around the world could be pointed accurately at them.

INTERNATIONAL EXPANSION. In establishing the overseas stations, Rechtin insisted that they be operated by local nationals. The best possible performance from each station, he reasoned—and experience was to prove him right—could be obtained from professionals "proud of their work, held responsible, and cooperatively competitive in spirit."

Visiting Americans might be vulnerable to homesickness or become uncomfortable in foreign surroundings over the long haul, and their performance might suffer, Rechtin thought. Local nationals, on the other hand, would not want their repute abroad to suffer if a mission failed, and so would toil perhaps harder at ensuring its success. "A bit of national pride certainly doesn't hurt!," Rechtin recalled in a 1992 historical paper.

In both Australia and South Africa, NASA and JPL contacted organizations eager to participate in setting up the network of antennas.

The Australian Department of Supply's Weapons Research Establishment (WRE) was managing the Woomera rocket range at which the British and Australian governments had been conducting high-altitude missile firings during the previous decade. The WRE's controller, or head official, was R. W. (Bill) Boswell. He believed the addition of an 85-ft-diameter antenna not only would help track those firings, but also ensure Woomera "a leading place in satellite and space research," as he noted in a Feb. 18, 1959, report.

In South Africa, Frank Hewitt, director of the Council for Scientific and Industrial Research's National Institute for Telecommunications Research (NITR), predicted in a January 1959 memorandum that an 85-ft antenna would be the "most valuable scientific tool it would be possible...to have," because between missions it could be used to conduct radio-astronomy research. Hewitt also believed that learning the techniques for operating the antenna would be fundamental to future intercontinental communications—an activity vital to a country so distant from Europe and the United States—and that it behooved the NITR to become familiar with them.

NASA sent site-survey teams to Australia in February and to South Africa in September and October 1959. With assistance from WRE, NITR, and other local officials, JPL selected and NASA endorsed two sites. In Australia they found a semicircular bowl-shaped valley opening to the south onto the edge of a dry lake bed known as Island Lagoon, about 30 km from the village of Woomera and about 50 km south of the head of the launch range. In South Africa, they found a Y-shaped valley near the town of Hartebeesthoek, 50 km northwest of Johannesburg and 30 km west of Pretoria.

NASA paid for the construction of the two overseas stations and sent field crews to erect the antennas and install the electronics. But WRE and NITR had the responsibility for acquiring the land, building access roads and support buildings, and hiring staff. Both agencies worked hard with NASA and JPL to get the stations ready in time for the new Ranger program of a series of lunar-impact probes, scheduled to be launched beginning in mid-1961.

By the time Ranger 1 blasted off on Aug. 23, 1961, both stations were indeed ready and the Deep Space Instrumentation Facility, renamed the Deep Space Network in 1963, became operational at long last.

FUTURE PERFECT. Foreseeing that space probes would become more sophisticated over the years and eventually travel beyond the orbits of Venus and Mars, Rechtin sought and received from NASA a continuing commitment that a relatively fixed portion—generally about 10 percent—of the Deep Space Network budget would be devoted to R&D. This commitment has allowed the network to develop over the years as mission requirements evolved.

An expanding deep-space program in the 1960s (further Rangers, Mariner flybys of Venus and Mars, Lunar Orbiters, Surveyor lunar soft-landings, and the series of Apollo manned lunar landings) bred the need for a second set of 26-meter-diameter (85-ft) antennas.

The first of those new antennas was installed at Goldstone, but Woomera and Hartebeesthoek were no longer the preferred sites overseas. Because of WRE's early difficulties in staffing the isolated Woomera station (in the outback about 320 km north of Adelaide) and insufficient housing for staff and their families, JPL sought an adequately shielded site nearer a population center. They found one in Tidbinbilla Valley, 18 km southwest of Australia's capital city Canberra, and a new ground station

there began operation in March 1965.

JPL was satisfied with NITR's operation of the station at Hartebeesthoek, but Rechtin was reluctant to expand there. He feared that worsening relations between the governments of the United States and South Africa (due to U.S. condemnation of South Africa's policies of apartheid) might suddenly limit or even end operations at Hartebeesthoek. And the more antennas there were in South Africa, the more expensive it would be to duplicate the station elsewhere.

So two new 26-meter antennas were installed near the Spanish towns of Rebledo de Chevala and Cebreros (50–65 km west of Madrid); they began operation in July 1965 and January 1967, respectively.

All the new antennas were operated at a different frequency: 2388 MHz. Budget cuts and a dwindling number of deep-space programs led NASA to close the Woomera and Hartebeesthoek stations in the 1970s. Age also forced the closure of the original Pioneer antenna at Goldstone; it is now a national monument.

A major evolutionary step in the Deep Space Network was the design and installation of 210-ft-diameter (64-meter) antennas at Goldstone in 1966 and at Tidbinbilla and Robledo de Chevala in 1973. They were built to support more sophisticated spacecraft sending data at a higher rate back to the earth.

The Deep Space Network has evolved in other ways as well. The remaining 26-meter antennas were extended to 34 meters in diameter by building out from the rim of the existing dish; that expansion, done in 1978 (Goldstone) and 1980 (overseas), enabled them to receive transmissions at 8.4 GHz and increased the received signal strength as needed for the two Voyager outer-planet missions.

In addition, Goldstone in 1984, Tidbinbilla in 1985, and Robledo de Chevala in 1987 each received a 34-meter-diameter high-efficiency antenna (so-called because the precision with which the reflector surface was shaped maximized its signal-gathering ability). They allowed each station of the Deep Space Network to function as a three-element array (with one 64-meter and two 34-meter antennas at each site), permitting a higher data rate for the Voyager missions to Jupiter and Saturn.

Still higher data rates, needed for the Voyager 2 encounters with Uranus in 1986 and Neptune in 1989, were obtained through two techniques. First, the existing stations functioned as elements in even larger temporary arrays, which included the CSIRO's 210-ft (64-meter) radio telescope in Parkes, Australia, in 1986 and 1989, and the National Radio Astronomy Observatory's Very Large Array (VLA) in New Mexico in 1989. Second, the 64-meter antennas were expanded to 70 meters in diameter in 1986 at Robledo de Chevala, in 1987 at Tidbinbilla, and in 1988 at Goldstone. This expansion increased the effective signal capture of these antennas by 50 percent.

The latest step in the Deep Space Network's evolution is the design of 34-meter multifrequency beam-waveguide antennas, in which weather-sensitive microwave components were to be put in an equipment room in the antenna's pedestal rather than being exposed to wind and rain on the rotating and dipping main reflector. The first of these new antennas was installed for research and development at Goldstone in 1990; the first antenna to support space missions is expected to become operational next year.

> The expansion of JPL's communications system into a three-station worldwide network was not a foregone conclusion

TO PROBE FURTHER. Craig B. Waff is completing a book for the Jet Propulsion Laboratory (JPL) on the history of the Deep Space Network based on published sources, oral history intverviews, and unpublished documents in archives in Australia, South Africa, Spain, and the United States. Photocopies of the documentation that supports the book (and this article) will be deposited in the JPL archives.

Waff's article, "Designing the United States' Initial 'Deep Space Networks,'" published in *IEEE Antennas and Propagation Magazine*, Vol. 35, no. 1, February 1993, pp. 49–57, details the choices of antenna design, operating frequency, and antenna location made by Space Technology Laboratories and JPL for supporting the Pioneer lunar-probe attempts of 1958–59.

William R. Corliss's *A History of the Deep Space Network* (NASA CR-151915, 1976) is an earlier work based primarily on published documents. Edward Mayes Walters used unpublished documents from the headquarters of the National Aeronautics and Space Administration (NASA) to discuss the diplomatic process that led to the establishment of the Woomera and Tidbinbilla Deep Space Network stations and other NASA facilities in Australia; his analyses appeared in his unpublished Ph.D. dissertation, "The 'Partnership' Philosophy: Australian-American Space-Tracking Relations" (University of Georgia, 1970).

Eberhardt Rechtin described how the Deep Space Network anticipated future requirements and developed means to meet them in his article, "Long-Range Planning for Deep Space Network," published in *Astronautics & Aeronautics*, Vol. 6, no. 1, January 1968, pp. 28–35.

The major role that national prestige played in stimulating the U.S. space program is discussed by Walter A. McDougall in his article, "Sputnik, the space race, and the Cold War," published in in *Bulletin of the Atomic Scientists*, Vol. 41, no. 5, May 1985, pp. 20–25.

For accounts of JPL's participation in the early days of NASA's unmanned solar-system exploration program, see Clayton R. Koppes, *JPL and the American Space Program: A History of the Jet Propulsion Laboratory 1936–1976* (Yale University Press, 1982); Joseph N. Tatarewicz, *Space Technology and Planetary Astronomy* (Indiana University Press, 1990); William E. Burrows, *Exploring Space: Voyages in the Solar System and Beyond* (Random House, 1991); and R. Cargill Hall, *Lunar Impact: A History of Project Ranger* (NASA SP-4210, 1977).

For an account of the expansion of the Deep Space Network in the 1970s, see Craig B. Waff's article, "The Struggle for the Outer Planets," published in *Astronomy*, Vol. 17, no. 9, September 1989, pp. 44–52.

ACKNOWLEDGMENTS. The author would like to thank Nicholas A. Renzetti of JPL, Pasadena, and Sylvia D. Fries and Roger D. Launius of NASA Headquarters, Washington, D.C., for supporting the contract under which the research for this article was conducted; Eberhardt Rechtin, professor of engineering at the University of Southern California, as well as many other current and former staff members of the Deep Space Network in Australia, South Africa, Spain, and the United States, for agreeing to be interviewed about their involvement with the network; and archivists at JPL, the NASA Headquarters History Division Office, the Canberra and Melbourne branches of the Australian Archives, and the Council for Scientific and Industrial Research in Pretoria, South Africa, for locating historical documents. The author is particularly grateful to Ray Lloyd of the Australian Space Office for facilitating his research in Australia.

ABOUT THE AUTHOR. Craig B. Waff is a technical writer in the TDA-DSN Documentation Group at the Jet Propulsion Laboratory, a NASA research center in Pasadena operated by the California Institute of Technology. Before taking this position last October, he worked under two three-year contracts to JPL, researching and writing histories of NASA's Project Galileo and of the Deep Space Network. Waff, who received a Ph.D. in the history of science from Johns Hopkins University in 1976, was a co-winner of the National Space Club's 1989 Dr. Robert H. Goddard Historical Essay Award. He also has a keen interest in the history of baseball.

1993 Major Medalists

The IEEE honors 14 outstanding contributors

IEEE Medal of Honor
Karl Johan Åström

Karl Johan Åström (F), has received the IEEE's 1993 Medal of Honor "for fundamental contributions to theory and applications of adaptive control technology." The award, as well as the IEEE major medals to 13 honorees, was presented at the IEEE Honors Ceremonies in Chicago on Feb. 27.

Åström's interests range widely in the areas of automatic control, stochastic control, system identification, adaptive control, computer control, and computer-aided control engineering. He has published five books, among them *Adaptive Control* (with B. Wittenmark). A contributor to several other books, he has also written many papers and is the owner of three patents.

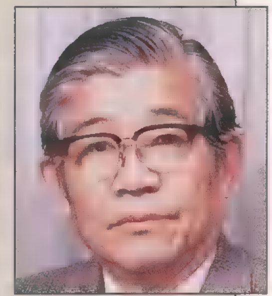
Since 1965, Åström has been professor and chair of the automatic control department at Lund Institute of Technology/University of Lund in Lund, Sweden. He has also been a visiting professor at universities in the United States, Europe, and Asia. In 1961 he joined IBM's Nordic Laboratory, where he worked on the theory and applications of computerized process control. He taught at the Royal Institute from 1955 to 1960, while simultaneously working on inertial guidance for the Research Institute of National Defense in Stockholm.

Åström is a vice president of the Royal Swedish Academy of Engineering Sciences and a member of the Royal Swedish Academy of Sciences. In 1990 he received the IEEE Field Award in control systems science and engineering. He has been a consulting editor for *IEEE Transactions on Automatic Control* and is an editor of *Automatica* and other journals.

IEEE Edison Medal
James H. Pomerene

James H. Pomerene (LF), IBM fellow and senior manager–processor organization, at IBM Corp.'s T.J. Watson Research Center, Yorktown Heights, N.Y., received the Edison Medal "for outstanding contributions to the development of computer architecture, including pipelining, reliable main memory, and memory hierarchies."

Pomerene joined IBM in Poughkeepsie, N.Y., in 1956, where he helped develop the Harvest computer. He directed the preliminary design of the Parallel Network Digital Computer, an early parallel machine. In the 1940s at the Institute for Advanced Study in Princeton, N.J., he worked with John von Neumann and Herman Goldstine on the prototype for such machines as Maniac, Oracle, and Illiac. Pomerene was appointed an IBM fellow in 1976 and soon transferred to the Research Division. He currently heads a group investigating improvements in processor organization.



IEEE Lamme Medal
Masayuki Ieda

Masayuki Ieda (LF), professor emeritus, Nagoya University, Nagoya, Japan, and professor, department of electrical engineering, Aichi Institute of Technology in Toyota, received the Lamme Medal "for outstanding contributions in developing electrical insulation technology and new insulating materials for high-voltage electric power apparatus and cables."

In the early 1950s, Ieda recognized the potential applications of synthetic polymers to electric power apparatus and cables. Subsequently, he introduced materials science approaches to the development of new insulating polymers. Ieda was a pioneer in elucidating the electrical properties of these materials, including electrical conduction, charge transport, and electrical breakdown phenomena.The author of more than 390 papers and 14 books, he has taught at Nagoya University since 1949. He is a past president of the IEE of Japan.

IEEE Founders Medal
Kenneth H. Olsen

Kenneth H. Olsen (LF), former president and chief executive officer of Digital Equipment Corp., Maynard, Mass., was awarded the Founders Medal "for technical and management innovation, and leadership in the computer industry."

Olsen founded Digital in 1957 and served as its president until his retirement last October. Under his direction, the company grew from three employees to become the world's leading supplier of networked computer systems, software, and services. He also worked at the Massachusetts Institute of Technology's Digital Computer Laboratory, and he served on the Computer Science and Engineering Board of the National Academy of Sciences, Washington, D.C., and on the President's Science Advisory Committee. He is a member of the National Academy of Engineering.

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IEEE Education Medal
Ronald A. Rohrer

Ronald A. Rohrer (F), director of the Computer Aided Design Center at Carnegie Mellon University, Pittsburgh, received the Education Medal "for innovation in bringing electrical engineering practice into the classroom and merging academic research with industrial needs."

An early advocate of improving the training of engineering undergraduates, he received the American Society for Engineering Education's Frederick E. Terman Award in 1978, in part for instituting an applications-oriented electrical and computer engineering curriculum at the University of Maine. Rohrer joined the electrical and computer engineering faculty at Carnegie Mellon in 1985 and was appointed a professor there in 1989. Applications-oriented lower-division engineering courses were made a key component of the new curriculum in electrical and computer engineering at Carnegie Mellon in 1991.

IEEE Alexander Graham Bell Medal
Donald C. Cox

Donald C. Cox (F), executive director of radio research, Bellcore, Red Bank, N.J., received the Alexander Graham Bell Medal "for pioneering and leadership in personal portable communications."

Under Cox's leadership, the radio research division has made significant contributions in wireless access to networks for personal communications, including radio-link architectures and techniques, radio systems, radio propagation, infrastructure network, and low-power signal-processing technologies and architectures.

Cox was a member of the technical staff at Bell Laboratories from 1968 to 1973, and he did communications system design at Wright-Patterson Air Force Base, Ohio, from 1960 to 1963. He received the Bellcore Fellow Award in 1991 and the Marconi Prize of the Institute for International Communications, Italy, in 1983.

IEEE Simon Ramo Medal
Claud M. Davis

Claud M. Davis (LF), president, D&N Associates (consulting engineers), Poughkeepsie, N.Y., received the Simon Ramo Medal "for leadership in the pioneering development of computer-aided air traffic control systems."

Employed by IBM Corp. from 1950 until his retirement in 1989, Davis held both management and technical positions in computer systems design and development. His systems design concepts were applied in the IBM 9020 system used in the Federal Aviation Administration's Enroute Systems Central Computing Complex. For more than two decades this air traffic control system covered the 48 contiguous states of the United States.

Davis is a recipient of the Elmer A. Sperry Award for advancing the art of transportation.

IEEE Medal for Engineering Excellence
Bernard C. De Loach Jr.

Bernard C. De Loach Jr. (F), former department head at AT&T Bell Laboratories, Murray Hill, N.J., is one of three who share the Medal for Engineering Excellence "for engineering advances which led to the first demonstration of highly reliable semiconductor lasers."

De Loach joined Bell Telephone Laboratories' radio research department in 1956. He began working on microwave filters, then moved on to parametric amplifier research and the millimeter wave Impatt diode. Beginning in 1973, he supervised the project for developing a reliable semiconductor laser, in the course of which record laser lifetimes grew from 30 minutes to 1000 years. Partly because of this effort, AT&T entered the optical-fiber business, providing lasers for the first full experimental message service, among other early developments. De Loach retired in 1989.

Richard W. Dixon

Richard W. Dixon (F), director, lightwave devices laboratory, joined Bell Laboratories in 1965, working on the interaction of light and elastic waves in solids and liquids. In 1984 he became director of the lightwave devices laboratory, whose goal was the systematic improvement of gallium arsenide and indium phosphide laser performance and reliability. Subsequent growth in laser lifetimes to millions of years led to their worldwide application in terrestrial and undersea optical-fiber telecommunications systems, as well as in consumer products such as audio and video disk players.

Robert L. Hartman

Robert L. Hartman (F), supervisor, semiconductor laser reliability group, joined the laboratories in 1968. In collaboration with De Loach and others, he discovered the causes of degradation in semiconductor lasers and developed improvements in fabrication procedures that boosted laser lifetimes. In 1980 Hartman became supervisor of a semiconductor laser development group whose efforts ultimately led to the development of highly reliable lasers.

IEEE Honorary Member
Robert W. Galvin

Robert W. Galvin was named an Honorary Member of the IEEE "for distinguished leadership of Motorola Inc., and for his many beneficial contributions to quality processes, competitiveness, and public policy."

Under Galvin's direction, Motorola developed semiconductor technology for applications in computer-controlled two-way radio communications, national defense, and space exploration. Now a leader in paging, cellular telephony, and a variety of other wireless technologies, Motorola was a winner of the first Malcolm Baldrige National Quality Award in 1988.

Galvin is past chairman of the Industry Policy Advisory Committee to the U.S. Special Representative for Trade Negotiations to the Multilateral Trade Negotiations under the General Agreement on Tariffs and Trade (GATT). He is also chairman of Sematech, an industry-government research consortium.

Galvin started working part-time for Motorola in 1940, joining the company permanently in 1944. He became president in 1956 and was the senior officer at Motorola from 1959 until early 1990. As chairman of the executive committee, he continues to serve as a full-time officer.

IEEE Henrich Hertz Medal
Kenneth G. Budden

Kenneth G. Budden (nonmember), former emeritus reader in physics, Cavendish Laboratory, Cambridge, England, received the Henrich Hertz medal "for original contributions to the theory of electromagnetic waves in ionized media with applications to terrestrial and space communications."

From 1960 until his retirement in 1982, Budden led a group of Cavendish researchers that published numerous papers on such subjects as phase integral methods, wave interaction, coalescence of coupling points, radio windows, and resonance tunneling. From 1936 to 1939, he did experimental research on low-frequency radio wave propagation, and during World War II he designed ground radar equipment at the Air Ministry Research Establishment. He is the author of four textbooks on the effect of the ionosphere and magnetosphere on radio waves.

IEEE John von Neumann Medal
Frederick P. Brooks Jr.

Frederick P. Brooks Jr. (F), Kenan Professor of Computer Science, University of North Carolina, Chapel Hill, received the John von Neumann Medal "for significant developments in computer architecture, insightful observation on software engineering, and for computer science education and professional service."

In 1964 Brooks founded the computer science department at the University of North Carolina and chaired it for 20 years. His principal research was in virtual reality, and he is currently pioneering the use of force display to supplement visual graphics. At IBM Corp. between 1956 and 1965, he was an architect of the Stretch and Harvest computers, and his System/360 team was the first to achieve strict compatibility, upward and downward, in a computer family. He is given credit for the term "computer architecture."

IEEE Richard W. Hamming Medal
Jorma J. Rissanen

Jorma J. Rissanen (SM), research staff member, IBM Almaden Research Center, San Jose, Calif., received the Richard W. Hamming Medal "for fundamental contributions to information theory, statistical inference, control theory, and the theory of complexity."

A native of Finland, Rissanen has been with IBM Research since 1966, except for a year when he held the chair in control theory at Linköping University, Sweden. In 1974 he introduced arithmetic coding for data compression, eliminating the need for alphabet extension.

Rissanen is the author of over 100 papers and a book, and he holds nine patents. His work has changed the way statistical inference can be done, and established statistics as a new chapter in information theory.

Forum

(Continued from p. 22)

consider myself an engineer. However, sometimes I am dismayed by the narrow perspective shown by engineers.

Specifically, Christiansen's concern about the "legitimacy of technical expert witnesses" in liability law is particularly troubling. He is surprised by the "bias" of expert witnesses. He apparently feels this is somehow unethical. He seems to believe that all of the individual litigants have a duty to seek justice.

If our system, or any real world system, relies upon the good will of us all, we are doomed. The assumptions of universal good will and benevolence are the stuff of dreamers, theologians, and espousers of discredited socialist systems. Fortunately, we have inherited economic and legal systems that do not require absurd assumptions.

Our legal system finds justice by a process, not by reliance upon any individual. We have rule by law rather than rule by individuals. The system recognizes, even requires, that individuals advance their personal interests to the best of their ability. Of course they are biased. How could they possibly not be biased? The salesman is biased for his product, the engineer for his ideas, the litigant for his position. To argue otherwise is ridiculous.

Truth comes from the zealous search for and presentation of all competing ideas. The market, or the trier of fact, will find the best idea of truth and justice. We can and we must rely upon the impartiality of the jury. If one expert witness is a fool or dishonest, do you seriously believe that the other side cannot show this to the jury? Does any one side have a monopoly on wit and knowledge?

Expert witnesses are subject to relentless questioning about their qualifications and their testimony in depositions and on the witness stand in front of the jury. Only someone with a hidden agenda, a desire to tip the scales, would argue that all litigants should be restrained by their adversaries' perception of fairness.

The public at large, including engineers, displays an astonishing lack of understanding of our social systems. World events of the past few years should leave no doubt that command-type systems, systems relying upon benevolence and good will of individuals, simply do not work. People, ideas, and products must be allowed to compete. Our social systems are robust enough to provide that the best, the most worthy and just, will come out.

This is not to say that ethical problems do not exist. They exist where misrepresentations are made in the absence of a system to reveal fraud and deception. Examples are a producer's falsification of test results, a manager's falsification of staff requirements, or an employee's falsification of work records.

Emile M. Mullick
San Bernardino, Calif.

Looking for jobs

As a fellow Brooklynite, I enjoyed the profile of Eleanor Baum [February, pp. 42–44]. However, when Baum speaks of "a shortage of engineers," she shows a lack of New York street smarts. I suggest that she visit unemployment offices and defense contractors in suburban Long Island, New Jersey, and Connecticut. She will quickly discover not a shortage but a surplus.

A. David Wunsch
Lowell, Mass.

P.S. More about e-mail

I would like to write an addendum to your interesting article, "E-Mail pervasive and persuasive" [October 1992, pp. 22–33]. Iran has been accepted into the European Academic and Research Network (EARN). A node was established in January, and I am the network country coordinator

Ebrahim N. Mashhayokh
ebrahim@IREARN.BITNET

Corrections

On p. 50 of the November issue, the name of Tanner Research Inc.'s product should have been L-Edit/Pro.

In the diagram on p. 69 of the January issue, all the figures on the horizontal axis labeled submarine speed should be multiplied by 10 (10 km/h, 20 km/h, and so on).

In the February issue, the correct spelling of the cover illustrator's name is Marc Ericksen.

In the penultimate paragraph on p. 42 of the March issue, the telephone number of Intel Corp.'s literature department should have been 800-548-4725.

In Figs. 5 and 6 on pp. 51 and 52 of the March issue, the phrase "Amplified stimulated emission" should have been "Amplified spontaneous emission."—*Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contact: Forum, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017, U.S.A.; fax, 212-705-7453. The compmail address is ieeespectrum. The computer bulletin board number is 212-705-7308 and the password is SPECTRUM; for more information, call 212-705-7305 and ask for the Author's Guide.

Was This The
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Legal aspects

Reverse engineering: fair game or foul?

Joel Miller

Recognizing the growing demand for personal communications products, the engineering staff at Spark Gap Technologies Ltd. is hard at work developing a credit-card–sized video cellular telephone. Although they've completed the RF and user-interface portions of the device, there are problems with the display. The video-processing software is too slow for real-time applications, and the picture on the screen is washed out and barely visible in normal daylight. At this point, the project seems dead in the water.

All may not be lost, though. A competitor has succeeded in producing a viable display; if Spark Gap can reverse-engineer that device, it should be able to solve its problems. All it needs to do is analyze the chips in the unit and decipher their contents.

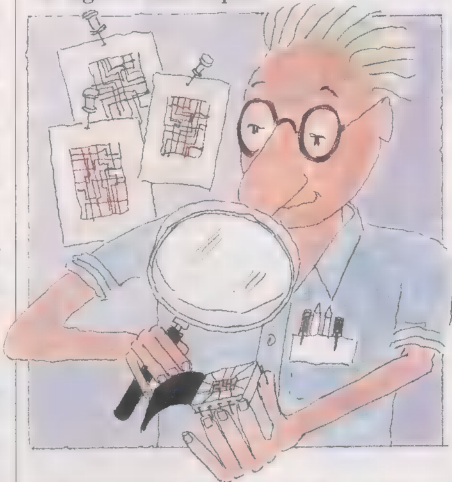
But could Spark Gap be sued if it bases some of its work on a competitor's device? Before jumping in, Spark Gap's engineers might want to review some recent court decisions illustrating the pitfalls of reverse engineering.

HOW DOES IT WORK? Reverse engineering is a time-honored technique of figuring out just what makes a competitor's product tick. Traditionally, one firm purchased the other's gadget, opened it up, and looked inside. Inspecting another's product was regarded as harmless and, in most instances—barring protection by a patent, copyright, or trademark—courts ruled that the details could be freely copied.

Before the advent of large-scale integration and software-based products, this principle was fairly easy to interpret and implement. Circuitry and systems were less complicated and it was easier to discern what kind of protections accompanied the design.

Today, things are different. Merely looking at the innards of a piece of electronics equipment may not be very enlightening. In many products, all there is to see is a circuit board covered with an assortment of chips. Function and operation are embedded in a combination of software, firmware, programmable arrays, and other media. To make matters worse, the legal protections surrounding such devices are not at all obvious, often being a combination of overlapping patents, copyrights, trademarks, and mask-work registrations.

One problem repeatedly encountered concerns the disassembly of the machine-readable pattern of 1s and 0s of object code to recreate the more understandable source code. Because software is often supplied in a ROM, one option is to decode the chip in order to learn how the device functions. However, the process of disassembling object code to generate the source code has been interpreted by some courts to be equivalent to making a copy. And copying is the very act prohibited by the copyright laws, as only the copyright owner and whomever he or she permits have the right to make copies.



Gus Sauter

Accolade Inc., San Jose, Calif., a manufacturer of computer entertainment products, faced this issue recently. To produce game cartridges compatible with those of Sega Enterprises Ltd. of Tokyo, Accolade reverse-engineered Sega videogame programs to discover the elements required for compatibility. The reverse engineering yielded the source-code equivalent of Sega's programs, from which Accolade developed its own original but compatible source code. Sega objected, claiming that Accolade violated the copyright by compiling Sega's source code.

Agreeing that Accolade had infringed the copyright, the trial judge granted Sega an injunction in April of last year, barring Accolade from "disassembling, translating, converting or adapting the copyrighted object code in [Sega's] game programs," in effect forcing Accolade out of the market. The fact that Accolade's undertaking was only an intermediate step in the process of making its own product did not save it from being an infringement.

FAIR USE EXCEPTION. Shortly after, to Accolade's relief, an appellate court dissolved the injunction. In a subsequent opinion released last October, the higher court ruled that the act of compiling source code is excused under the fair use exception to the rule prohibiting copying, if that is the only way to obtain access to nonprotectable elements of the program, such as, in this instance, those concerning compatibility. [For more on fair use, see this column, July 1992, p. 20.]

Here, Accolade was trying to learn just enough of the details of Sega's products to enable it to manufacture compatible cartridges. Likewise, in light of *Sega*, Spark Gap would be permitted to compile its competitor's source code if it could show that this would be the only way of learning the nature of undisclosed and otherwise unprotected elements in its competitor's software.

KEEP IT CLEAN. But even if Spark Gap relies on the fair use exception, proving that it did not copy outright from its competitor's product can be sticky. One technique for software emulation that has had some success is the use of a "clean room"—that is, a work area isolated from the emulated product.

Initially, an analysis is made of the other's program to learn the overall functions it performs. Then, a programmer isolated from the competitor's program writes original code that imitates those functions.

A "clean room" product was examined for infringement in the case reviewed in the January column—*Computer Associates International Inc. v. Altai Inc.*, 1992. There, the court concluded that Altai's Oscar 3.5 program did not infringe the copyright on Computer Associates' Adapter, even though Altai's work was based on a copy of Computer Associates' source code that an Altai employee had misappropriated. Note, however, that the same court stated in a later, amended opinion that Computer Associates might well be entitled to a judgment in its favor on the basis of misappropriation of trade secrets, and directed the trial court to revisit this issue.

The "clean room" concept would probably not help in Australia. In resolving a dispute between Autodesk Australia Pty Ltd. and Dyason, an Australian court concluded in 1989 that the need to analyze the functions performed by another's device is inconsistent with independent development, foreclosing a finding of noninfringement.

IT'S IN THE CHIPS. In addition to software, Spark Gap might wish to analyze the structure and circuitry of its competitor's integrated circuits. The U.S. Semiconductor Chip Protection Act, passed in 1984 to protect IC topologies, specifically allows for reverse engineering. Both Japan and the European Community have enacted similar legislation.

The U.S. chip act gives the owner of a mask work—literally, the masks used to produce an IC—the exclusive right to reproduce a semiconductor mask work by "optical, electronic, or any other means." The protection covers circuits that are original and have a design that is not "staple, commonplace, or familiar in the semiconductor industry."

The chip act's reverse-engineering exception permits someone to "reproduce the mask work solely for the purpose of teaching,

analyzing, or evaluating the concepts or techniques embodied in the mask work or the circuitry, logic flow, or organization of components used in the mask work...." In other words, the chip act allows one to buy a product, remove a chip, peel back its layers, and analyze the underlying circuitry to find out how the chip works.

Nevertheless, the reverse-engineering provision does not permit one to simply copy the chip. That is apparently why Advanced Micro Devices Inc. (AMD) of Sunnyvale, Calif., got into difficulty with Brooktree Corp. of San Diego, Calif. Brooktree charged that AMD's color palette chip violated some Brooktree patents and mask works.

Despite efforts to independently develop a static RAM (SRAM) cell for the palette chip, AMD apparently failed and instead succumbed to copying Brooktree's layout. After first seeing Brooktree's SRAM cell design, an AMD engineer tried to design an SRAM cell having six transistors, and then one having eight. Neither worked. Finally, the engineer turned to a 10-transistor arrangement, precisely the configuration used by Brooktree. Not surprisingly, this worked.

EUREKA? Although AMD claimed that it developed its device independently and not by copying, the fact remained that its engineer had seen the Brooktree layout beforehand. Ultimately a jury decided that it had been copied into the AMD design. Therefore, the reverse-engineering defense was of no assistance to AMD.

Two points are worth noting about the *Brooktree* case. First, AMD argued that because it did not copy the entire mask, there could be no infringement. The court disagreed, pointing out that it is possible to infringe by copying just a portion or even the general layout of the chip's components. Second, AMD offered up a voluminous paper trail to prove that its chip was the result of reverse engineering. Although a paper trail may suggest that a product is original, even a warehouse of records will not establish originality if there was illegal copying.

IS IT WORTH IT? While Spark Gap's engineers should not necessarily swear off reverse engineering, they should proceed cautiously. As a general rule, while it is okay to look, they should be very careful about what they take—and how they take it.

Since it may not be clear what is protected in a product nor how such items are protected, it is imperative that Spark Gap's engineering team know enough about the legal principles or seek out someone who can advise them. In this era of technical and legal sophistication, proceeding with ignorance may well be interpreted as a wilful act of infringement. The penalties could be severe.

Patent rights revisited

Keeping a proper record is one aspect of preserving one's patent rights. In *Gould v. Shawlow*, 1966, the case discussed in this column last October [p. 19], the inventor Gordon Gould failed to secure a patent on the laser because he was unable to prove to the satisfaction of the court that he had invented his device before the team from Bell Laboratories. Two points need to be clarified: exactly why he was unable to support his claim, and how he might have avoided the situation.

Although the court agreed that Gould's notes predated the Bell Labs effort, the notes did not describe an "operative" device—a more detailed description was necessary to establish that Gould had invented his device at the time the notes had been written. Moreover, Gould had no other means of proving a prior conception of the laser.

This problem might have been avoided had the notebook been witnessed by someone technically skilled who could later have testified on Gould's behalf. Thus, the preferred (although not mandatory) practice is to have a knowledgeable witness corroborate a laboratory notebook, using the phrase "read and understood."

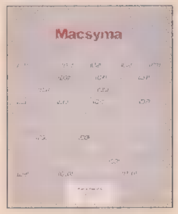
Joel Miller is an attorney in private practice in West Orange, N.J.

Software reviews

Macsyma for Windows

Kenneth R. Foster

PC Macsyma.
Macsyma Inc.
Requires a PC with an Intel 80386 microprocessor (or equivalent) and math coprocessor, or a 80486-based system, with a hard disk with approximately 40 MB free space. A minimum of 8 MB of RAM is required; the vendor recommends 12–16 MB.
US $ [349]



Macsyma is a national treasure, one that has been under development since 1968 at the Massachusetts Institute of Technology, Cambridge, in a joint effort with private industry. It has been used widely on mainframes and workstations for many years by scientists and engineers, and now its present vendor, Macsyma Inc., is offering a handsome version for Microsoft Windows at a remarkably low price.

A high-end mathematics program, Macsyma makes use of symbolic manipulation (SM) programs that solve algebraic or differential equations, evaluate integrals, do series expansions, and carry out many other mathematical tasks analytically.

The version I tested was based on Macsyma Release 417, an incremental update of the standard product. The addition is a graphical user interface, which is characteristic of programs for Microsoft Windows and greatly improves Macsyma's user-friendliness. The user can enter most commands, at least in part, by mouse from a menu.

The extensive on-line help includes a tutorial on Macsyma, sample usage of more than 400 commands, and many demonstration programs—all accessible by mouse from the menu. Besides its on-line help, Macsyma comes packaged with a well-written 250-page introductory guide and a 600-page manual (dated 1988) that is clearly written but assumes considerable mathematical sophistication on the part of its readers. The user's guide and the help menus should enable a novice to use the program productively very quickly. But full mastery of the program, and the ability to write programs in the Macsyma language, are different matters entirely.

The Windows environment has other benefits as well. Macsyma displays its output in an attractive graphical format, with well-formed integral signs and parentheses. Users may "cut and paste" graphics and equations from Macsyma into other Windows applications. The graphics are superb.

On my system, a PC based on the Intel 80486 microprocessor with 20 MB of RAM running at 33 MHz, the program ran smoothly. However, its performance on a system with 8 MB of RAM (the minimum specified by the vendor) was painfully slow; a more reasonable minimum is 12–16 MB of RAM. The program also needs 18 MB of hard-disk space for storage and another 10–20 MB for virtual memory.

Macsyma's special strengths are in symbolic manipulation, where it is more comprehensive and arguably more reliable than such competing programs as Maple and Mathematica. Of these three programs, Macsyma is the only one that asks the user for additional information about an expression as it evaluates it, or that allows the user to specify the range of a variable easily.

On the other hand, Macsyma is slower, and demands a larger system. Users with heavy mathematics needs should insist on Macsyma, if not on their systems, at least on a computer down the hall. *Contact: Macsyma Inc., 20 Academy St., Arlington, Mass. 02174; 617-646-4550; fax, 617 646-3131; or* **circle 115.**

Kenneth R. Foster (F) is associate professor of bioengineering at the University of Pennsylvania. His e-mail address is kfoster@eniac.seas.upenn. edu.

Words, pictures, and numbers in one file

John R. Hines

Mathcad 3.1.
MathSoft Inc. A technical equation-solving program that requires at least an IBM-compatible PC with at least a 286 microprocessor, a VGA display, a mouse, 7 MB of free disk space, and 2 MB of memory with Windows 3.x under DOS 3.1 or higher. US $495. MathSoft is also available for the Macintosh and for Unix-based workstations.

Mathcad 3.1, a program from MathSoft Inc. for solving technical equations, is fully compatible with Windows 3.1, including TrueType fonts. This update of the 3.0 version contains full object-linking and -embedding (OLE) client support, which is its most important feature.

Also, this program supports color surface plots with user-controlled rotation and light sources. And it contains software to link Mathcad to electronic handbooks from CRC Press and McGraw-Hill, traditional publishers of hardcopy electrical and electronic reference books.

With OLE client support, Mathcad users can build and edit, as I did, compound documents that contain segments created and edited by Mathcad as well as segments (objects) created and edited by other programs linked to the Mathcad document.

Color surface plots are a plus for engineers and scientists who need to see three-dimensional renderings. Unfortunately, surface plots take much computing power: a 50-by-50 cell surface plot of a 3-D sinusoidal surface took 2 minutes on the 386SX that I use at home and 20 seconds on the 486 that I use at work.

Electronic handbooks have more promise than the other new features in Mathcad 3.1. Users may obtain equations or tabular data from standard references like MathSoft's *Treasury of Methods and Formulas* or CRC's *CRC Materials Science and Engineering Handbook* electronically.

Unfortunately, the interface to the electronic books needs some work. Accessing information in an electronic handbook is slow. Finding a new topic in the *Treasury* took maybe 30–40 seconds using a 386SX computer with a hard disk having an access time of 40 ms. Also, the access to the electronic handbooks works differently from on-line help for Windows or for most programming languages.

Running Mathcad requires at least a 386SX with a math coprocessor and at least 4 MB of memory. On any PC without a 486, the WAIT message occurs frequently. But the program does an excellent job of solving equations, plotting data, and creating documentation. Note: Mathcad 4, an update, became available at press time. *Contact: MathSoft Inc., 201 Broadway, Cambridge, Mass., 02139; 617-577-1017 or 800-628-4223; fax, 617-577-8829; or* **circle 116.**

John R Hines (A) is silicon sensors engineer at Honeywell Inc.'s MicroSwitch Division, Richardson, Texas.

COORDINATOR: Gadi Kaplan

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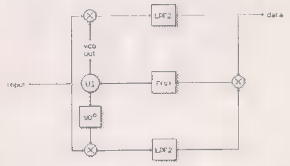

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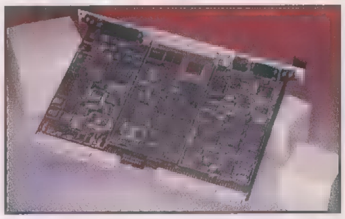

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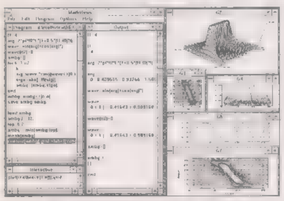

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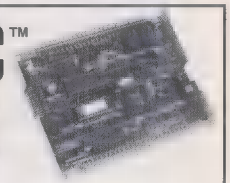

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(Continued from p. 18F-T)

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American Control Conference—ACC '93 (CS); June 2–4; Westin St. Francis, San Francisco; Bonnie S. Heck, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, Ga. 30332-0250; 404-894-3145; 404-853-9171.

47th Annual Symposium on Frequency Control (UFFC); June 2–4; Salt Lake City Marriott, Salt Lake City, Utah; Gary R. Johnson, Sawyer Research Products Inc., 35400 Lakeland Blvd., Eastlake, Ohio 44095; 216-951-8770.

Conference on Insulating Films on Semiconductors—Infos '93 (ED); June 2–5; Delft University of Technology, the Netherlands; C.H. Klein, Conference Office Infos '93, DIMES, Delft University of Technology, Box 5053, 2600 GB Delft, The Netherlands; (31+15) 783 868; fax, (31+15) 622 163.

Information Theory Workshop (IT, Tokyo Section); June 4–8; Fuji Institute of Education and Training, Shizuoka, Japan; Ryuji Kohno, Division of Electrical and Computer Engineering, Yokohama National University, Tokiwadai, Hodogaya-ku, Yokohama 240, Japan; (81+45) 335 1177.

International Conference on Plasma Sciences—Icops (NPS); June 7–9; Sheraton Landmark Hotel, Vancouver, B.C.; Andrew Ng, University of British Columbia, Department of Physics, 6224 Agricultural Rd., Vancouver, B.C. V6T 2A6, Canada; 604-822-3191; fax, 604-822-5324.

Signal Processing Workshop on Higher Order Statistics (SP); June 7–9; Stanford Sierra Camp, South Lake Tahoe, Calif.; A. Swami, 1046 Redondo Blvd., Los Angeles, Calif. 90019; 213-931-0261; fax, 213-931-0914; or Georgios B. Giannakis, Department of Electrical Engineering, University of Virginia, Charlottesville, Va. 22903-2442; 804-924-3659.

International Solid-State Sensors and Actuators Conference (ED); June 7–10; Pacific Convention Plaza, Yokohama, Japan; K. Takahashi, Department of Physical Electronics, Tokyo Institute of Technology, Ohokayama Meguro-Ku, Tokyo, Japan.

12th International Conference on Consumer Electronics (CE); June 8–10; Westin Hotel O'Hare, Rosemont, Ill.; Diane D. Williams, Conference Coordinator, 67 Raspberry Patch Dr., Rochester, N.Y. 14612-2868; 716-392-3862.

Eighth Conference on Real-Time Computer Applications in Nuclear, Particle and Plasma Physics (NPS, Vancouver Section); June 8–11; University of British Columbia Conference Center, Vancouver; Ruth Risto, Triumf, 4004 Wesbrook Mall, Vancouver, B.C., V6T 2A3 Canada; 604-222-1047; fax, 604-222-8325.

International Electronic Manufacturing Technology Symposium—IEMT '93 (CHMT); June 9–11; Kanazawa City Cultural Hall, Kanazawa, Japan; Nobuo Iwase, Display Laboratory, R&D Center, Toshiba Corp., 1 Komukai Toshiba-chu, Saiwai-ku, Kawasaki 210, Japan; (81+44) 549 2148.

International Workshop on Charge-Coupled Devices and Advanced Image Sensors (ED); June 9–11; University of Waterloo, Ontario; Savaas Chamberlain, University of Waterloo, Electronic Computer Engineering Department, Waterloo, Ont., Canada N2L 3G1; 519-888-4598; fax, 519-746-6321.

Third Wireless Personal Communications Symposium (COM, VTO); June 9–11; Virginia Tech Campus, Donaldson Brown Center for Continuing Education, Va.; Jack Lilly, Donaldson Brown Center for Continuing Education, Corner of College Avenue and Otey Street, Rm. 445, Blacksburg, Va. 24061-0104; 703-231-4849.

Minicourse on Environment and Energy Issues in Plasma Science (NPS); June 10–11; Sheraton Landmark Hotel, Vancouver, B.C., Canada; Wallace Manheimer, Code 6707, Naval Research Laboratory, Washington, D.C. 20375; 202-767-3128; fax, 202-767-1607.

Symposium on Computer-Based Medical Systems—CBMS (C, EMB, et al.); June 13–16; University of Michigan League, Ann Arbor; Timothy Kriewall, Sarns 3M Health Care, 6200 Jackson Rd., Box 1247, Ann Arbor, Mich. 48106-1247; 313-663-4145.

Workshop on Qualitative Vision (C); June 14; Omni Park Central, New York City; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Microwave and Millimeter Wave Monolithic Circuits Symposium (ED); June 14–15; Marriott Hotel, Atlanta, Ga.; Charles Huang, LRW Associates, 1218 Balfour Dr., Arnold, Md. 21012; 301-647-1591; fax, 301-647-5136.

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tem of Units (SI) prefixes that were adopted in 1991. The rules for handling unit symbols have been modified slightly to bring them more closely into conformance with international standards, and the table of conversion factors has been thoroughly revised to make it easier to use.

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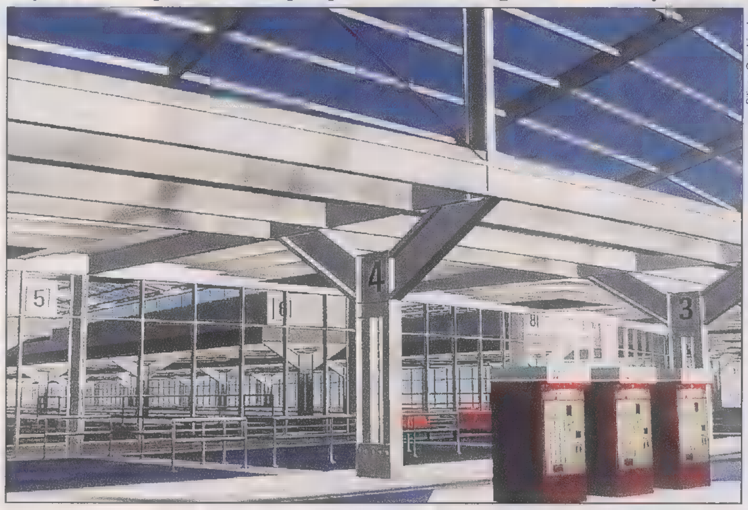
Graphics

Urban visions for sale

Clustered in the London offices of Digital Pictures Ltd. are a dozen workstations whose monitors are like windows on a world-to-be. Through these screens, in lively detail, shine scenes featuring the buildings and city landscapes that are the dreams and livelihood of Digital Pictures' clients. From the company's workstations have emerged animations depicting an airport in Hong Kong, a marina complex in Barcelona, a shopping mall in Bangkok, and other scenes.

The business, scarcely two years old, accounts for only a minor part of Digital Pictures' overall income, most of which stems from television commercials and station identifications. But the work does more than improve the balance sheet, bringing the company into contact with challenges and clients it would not otherwise encounter. "It's quite an interesting environment to function in," said Simon Robinson, the company's software chief.

"You can't say to a client, 'sorry, it's not possible.' You have to *make* it possible. We actually budget for some R&D in a client's project, so we can give them the edge they're looking for." The clients for Digital Pictures' urban animations are mostly developers or public officials, he noted, and the edge they are typically seeking is stunning realism or some eye-catching effects to build support for their proposed constructions.



Silicon Graphics Inc.

In fact, such realism and pizzazz are what put most such projects in the domain of commercial graphics companies like Digital Pictures, according to Jay Williams, the company's managing director. Most large engineering and architectural firms have modeling and simulation capabilities, too, but these are generally for in-house use or at most relatively straightforward demonstrations for prospective clients.

Software used by commercial firms, on the other hand, is apt to be more advanced graphically and capable of dramatic effects, according to Williams. Digital Pictures itself relies on a custom graphics software environment, called DigiPix, that occupies more than half a million lines of C code.

The company's first customer for its urban and architectural modeling was the British government, which needed an animation to persuade businesses to exhibit at the pavilion it was planning for Expo '92 in Seville, Spain. This in turn led to an assignment from Hong Kong's colonial government, which was seeking to drum up capital for an airport planned for construction on the outlying island of Chek Lap Kok [see photo]. That job led in turn to a contract from the Catalonian authorities, who wanted a video to fan public enthusiasm for Port 2000, the planned redevelopment of Barcelona's harbor and marina area.

In both projects, Digital Pictures played the same sort of role, that of a Hollywood special effects studio, inserting animation and graphics into "live action"—digitized film shot on location by local production companies (Salon Films in Hong Kong and Division Video in Barcelona). "Because we are dealing with what is effectively a program to be viewed by an audience, we look at it like a small film," Williams explained.

Projects begin with a script describing the sequence of events during the video. The scripts generally revolve around a journey, or "flight," over and through the metropolitan area where the building or development is planned. The perspective is as though shot from a camera floating above an avenue approaching the development, or perhaps high above it, showing its place in the surrounding metropolis. A popular graphics effect, used in both the Hong Kong and Barcelona projects, suggests how the area around the development will change over time; the effect resembles time-lapse photography, with buildings appearing or disappearing, the landscape changing, trees growing, and so on.

After the script come the storyboards, which are a series of drawings showing key images, as exactly as possible, as they will be seen in the video. Then the animation itself is created with the use of DigiPix and usually integrated with live-action footage. Features within DigiPix allow animators to model buildings, landmarks, and other elements independently and keep the details on mass storage devices. All the workstation memory need do is keep track of where these features are in the model, and where the flight path is. DigiPix also has stochastic tools enabling animators to contrive an image of a building in a certain architectural style, and then spin off an endless variety of subtly different clones to line a boulevard or develop a neighborhood, say.

According to Williams, the key question in producing the graphics is how much detail to include. Animators for the most part work from architectural plans and drawings. Sometimes computer models are available; but, having been created for a different purpose, these models are almost invariably either too complex or too crude for Digital Pictures' purposes.

High aerial views also present a dilemma. A big city is far too complex to model in exhaustive detail, so the animators must achieve a degree of verisimilitude with only a handful of key visual cues—the layout of the main avenues and a few landmarks. In general, animators strive for the highest level of detail compatible with very real temporal, financial, and technological constraints.

As it is, Robinson points out, two or three minutes' worth of final animation (a probable amount for a 5–10-minute video including live action) can easily fill up several hundred megabytes with the images and the models describing where they are, the flight path around and through them, time-lapse effects, and so on. To devise the images, Digital Pictures depends on a stable of Silicon Graphics Inc. workstations, ranging from 40/50 models to the recently introduced IRIS Crimson VGX. When the animations are finally done and being transferred to video, each frame can take an hour to render—and in the phase alternation line (PAL) video format used by Digital Pictures, there are 25 frames per second.

A typical project to produce three minutes' worth of high-quality animation might take two months and involve all six of the company's animators and all 13 workstations. The fee of £150 000 and up is like "spit in the ocean," Williams figured, in comparison to the overall budget for large construction jobs.

COORDINATOR: Glenn Zorpette

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

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Baylor University - The Department of Engineering and Computer Science invites applications for a tenure track position at the Assistant/Associate Professor level. A PhD and a strong interest in undergraduate teaching is required. The department offers a General Engineering Program with Electrical and Mechanical Options leading to the Bachelor of Science in Engineering degree. The program is characterized by excellent facilities and a faculty of ten which offers highly personalized instruction in a Christian environment to approximately 250 students majoring in engineering. The applicants are expected to have a strong background in electrical engineering with particular strengths in electronic devices, analog and digital circuit design, and electromechanical energy conversion. Applicants must also have demonstrated skills using the computer as a design tool and teaching laboratory courses. Although the department prefers to fill the position to begin in Fall 1994, applications are invited for Fall 1993. For full consideration applications should be received by April 15, 1993. However, applications will be accepted until the position is filled. Please send a complete resume with three references to Dr. James D. Bargainer, Chairman, Department of Engineering and Computer Science, P.O. Box 97356, Waco, TX 76798. Baylor University is a Baptist university affiliated with the Baptist General Convention of Texas. As an affirmative action/equal employment opportunity employer, Baylor encourages minorities, women, and persons with disabilities to apply.

The University of Kentucky invites applications for an open tenure-track position in the area of Power Electronics and Electric Drives. Applicants must hold an earned Ph.D. in Electrical Engineering. The position requires demonstrated potential for excellence in teaching and research. A strong commitment to teaching on the undergraduate and graduate level and to the development of a research program is required. Rank and salary are highly competitive and based upon experience and qualifications. Applications should include a complete resume containing the names, addresses and phone numbers of at least three references. U.S. Citizenship or Permanent Residence required. Send applications to Dr. S.A. Nasar, Chairman, Department of Electrical Engineering, University of Kentucky, Lexington, KY 40506-0046. The University of Kentucky is an equal opportunity/affirmative action employer.

The Department of Electrical Engineering at The University of Maryland Baltimore County (UMBC) has an opening at the level of Research Associate. The position involves experimental research in the area of fiber optics including: fiber lasers; fiber sensors; modelocked fiber lasers; Photonic networks, nonlinear fiber logic gates, solid state lasers, and semiconductor lasers. A Ph.D. in Electrical Engineering or Physics and related experience is required. Send a detailed resume and the names of three references to Professor Gary M. Carter, Department of Electrical Engineering, UMBC, Baltimore, MD 21228. UMBC is an Affirmative Action/Equal Opportunity Employer.

Chair, Department of Electrical and Computer Engineering—Nominations and applications are invited for the Chair of the Department of Electrical and Computer Engineering to start August 16, 1993. A leading Jesuit university, Marquette University derives a distinctive character from the combination of its religious commitments, its location in a major city, its excellent faculty with diverse religious convictions, and its deep involvement in and dedication to undergraduate and graduate education and scholarly research. Of the 12,000 students at Marquette, 400 are undergraduate students and 180 are graduate students in the Electrical and Computer Engineering Department. The Department is housed in newly renovated facilities on an attractive campus in a vibrant city with supportive industries. The Department has 17 faculty with an annual budget of externally supported research totaling about $1M. Faculty participate in the several interdisciplinary College of Engineering Research Centers. Candidates for the position should have a doctorate, a superior record of research and professional activities, and teaching experience to qualify for the rank of professor with tenure. Applications and nominations should be sent to Dr. Jeffrey L. Hock, Associate Professor, College of Engineering, Marquette University, Milwaukee, WI 53233. Review of resumes will start May 15, 1993, but will be accepted until the position is filled. Marquette University is an equal opportunity, affirmative action employer.

Experimental Faculty Position, Optical Sciences Center, University of Arizona. The Optical Sciences Center of the University of Arizona is seeking an Assistant/Associate Professor, tenure track, specializing in the area of experimental quantum electronics/quantum optics. The successful candidate should have a proven track record after Ph.D. in one or more of the following areas: nonlinear materials, including semiconductors and second harmonic crystals, guided wave optics including fibers, solid state and semiconductor lasers, optoelectronic device physics and related materials, quantum optics, atom optics, cooling and trapping. Teaching graduate level courses and supervising graduate students is required. Salary for this position is commensurate with experience and qualifications. Applicants should forward a complete curriculum vitae and names of three references to Dr. Richard C. Powell, Director, Optical Sciences Center, University of Arizona, Tucson, Arizona 85721. Refer to position 93-100. The position will remain open until filled. University of Arizona is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

The University of Missouri-Columbia Department of Electrical and Computer Engineering invites applications for a tenure-track position at the assistant level in the areas of electrical engineering. Responsibilities include teaching undergraduate and graduate courses, student advising and developing and conducting sponsored research programs. Candidates must have an earned doctorate in Electrical Engineering or related disciplines, and the potential for, and commitment to, developing sponsored research. Candidates for the position must have an interest and background in molecular beam epitaxial growth. Interested applicants should send a resume, a description of research interests, and immigration status for non-United States citizens to: Jon Meese, Chariman, Department of Electrical and Computer Engineering, University of Missouri, Columbia, MO 65211. The University of Missouri is an Affirmative Action/Equal Opportunity Employer.

University of Alberta. The Department of Electrical Engineering invites applications for two tenure track positions, one in the area of Control Systems and one in Power Electronics or Power Systems and Control. Both positions are at the Assistant or Associate Professor Level (base levels $40,035.00 and $49,423.00 respectively). The successful applicants will be qualified to teach undergraduate and graduate courses in their area of speciality and in the Electrical Engineering core curriculum. As well, the applicants are expected to supervise both MSc and PhD graduate students and to demonstrate leadership in the development of a research program. Research areas of interest to the Department for the control systems area include, but are not limited to, systems engineering, robotics, control systems, biomedical applications, and power systems. Research areas of interest for the power electronics/power systems and control area include, but are not limited to, variable speed drives, power electronics, and power system control. Applicants should have a Ph.D. (or pending) in Electrical Engineering, demonstrated potential for developing an independent research program, a strong background in applied Engineering, and the potential and interest for interaction with industry and with other researchers. Applications will be accepted until June 30, 1993. The Department of Electrical Engineering at the University of Alberta has at present a 37-member teaching staff, approximately 100 graduate students, and admits 155 beginning undergraduate students each year. Excellent teaching and research facilities are available in the robotics laboratory and in the power electronics and controls areas. Opportunities for collaborative research include the Department of Chemical Engineering, the Department of Computing Science and research institutes such as the Alberta Microelectronic Center, The Laser Institute and Telecommunications Research Laboratories. To apply, send a curriculum vitae, the names of three referees and a statement of research interests to: Dr. C.E. Capjack, Chair, Department of Electrical Engineering, The University of Alberta, Edmonton, Alberta, Canada, T6G 2G7. Please indicate the position being applied for. The University of Alberta is committed to the principle of equity in

employment. The University encourages applications from aboriginal persons, disabled persons, members of visible minorities and women.

Cleveland State University, Department of Electrical Engineering, Faculty Position: Cleveland State University is seeking applications for a tenure track faculty position in the Computer Engineering area. Appointment will be at the Assistant or Associate Professor level with a competitive salary and rank commensurate with qualifications. Applicants must have earned Ph.D. in Computer Engineering or related areas of Electrical Engineering, a sincere commitment to teaching at both the undergraduate and graduate levels, and the ability to implement an independent research program. Industrial experience is desirable. The department offers a Computer Engineering option at the undergraduate level in cooperation with the Department of Computer and Information Science. The department has an ongoing relationship with NASA Lewis Research Center, which is in close proximity. Industry cooperation is facilitated by the Advanced Manufacturing Center of the College of Engineering. Salary: Negotiable. Deadline: May 1, 1993 or when position is filled, with ongoing screening of applications. Starting date: September 13, 1993. Send resume, publications and list of three references to: Dr. James H. Burghart, Chairman, Electrical Engineering Department, Cleveland State University, E. 24th & Euclid Ave., Cleveland, OH 44115. Non-U.S. citizens should include a statement of visa status and eligibility for employment. Equal Opportunity Employer, m/f/d. CSU provides reasonable accommodation for individuals with disabilities.

Columbia University. The Department of Electrical Engineering invites applications for faculty positions in VLSI Systems. A successful candidate must have a desire to teach at both the undergraduate and graduate level, and is expected to establish a strong independent research program preferably focusing on some key application area of VLSI systems; e.g., telecommunications, image/video processing, multimedia systems, computer visualization servers, etc. Both senior and junior candidates will be considered. A senior candidate is expected to have an outstanding track record in research and to be experienced in attracting funding. The research will be conducted in conjunction with the Center for Telecommunications Research, a large cross-disciplinary Engineering Research Center, sponsored by the National Science Foundation and industrial participants. Please send your resume and the names of three references to: Professor T.E. Stern, Chairman, Department of Electrical Engineering, Columbia University, 500 West 120th Street, Room 1312, New York, NY 10027. Minorities and women are encouraged to apply. Columbia is an equal opportunity/affirmative action employer.

Rutgers University. The Department of Electrical and Computer Engineering anticipates an opening and invites applicants for a tenure track position at the Assistant Professor level in the areas of circuit design and digital/analog electronics. Ph.D. in EE, or equivalent, and clear potential for distinguished performance in teaching and research is required. The successful candidate's duties will include teaching at the undergraduate and graduate levels, laboratory development, and establishment of scholarly activities in the area of specialization. CAD development, IC testing tools, IC cleanroom fabrication facilities and comprehensive computing facilities currently exist within the Department and the University. Opportunities exist for affiliations with several Rutgers high technology research centers and with local industry. Interested individuals should send a resume and the names of four references to Prof. B. Lalevic, Department of Electrical and Computer Engineering, Rutgers University, PO Box 909, Piscataway, NJ 08855-0909. Rutgers is an equal opportunity, affirmative action employer.

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Concordia University, Faculty of Engineering and Computer Science, Faculty Position in Avionics. Concordia University's Faculty of Engineering and Computer Science invites applications for a full-time tenure track position in Avionics. Teaching responsibilities include participation in the Faculty's graduate program in aerospace offered jointly with other Montreal universities. In addition, the successful candidate will be expected to exercise a leadership role in the development of this emerging field of research and graduate work at Concordia, and to strengthen R&D links with local aerospace industry, with other institutions and with the newly created Canadian Space Agency centered in Greater Montreal. The ideal candidate will have a Ph.D. in a related field of Electrical or Aerospace Engineering, will have taught and done research in Avionics, will have demonstrated abilities to forge university/industry links and will have had hands on experience in the specification and design of Avionic Systems for the aerospace industry. Experience in spaceborne radar and remote-sensing, satellite and other space systems will be an asset. The Faculty has over 110 full-time faculty members and is strongly committed to teaching and research excellence as well as industrial linkages. There are currently over 450 graduate students in the Faculty of whom 35 are in the aerospace program. In accordance with Canadian immigration requirements, priority will be given to citizens and permanent residents of Canada. Concordia University is committed to employment equity and encourages applications from women, aboriginal people, visible minorities and disabled persons. All things being equal, women candidates shall be given priority. Applicants should send a detailed resume and names of at least three references to The Dean, Faculty of Engineering and Computer Science, SGW Campus - H 907, 1455 de Maisonneuve Blvd. West, Montreal, Quebec, H3G 1M8, Canada. Fax: (514) 848-8646.

Stanford University, Department of Electrical Engineering - Faculty Opening. The Department of Electrical Engineering at Stanford University invites applications for a tenure-track faculty position in the field of high-speed circuits. Applicants should have an earned Ph.D., demonstrated research ability, and a strong interest in graduate and undergraduate teaching. The field of interest is broadly interpreted to mean the design of circuits employing novel and emerging mainstream semiconductor technologies to solve problems in high-speed electronic systems, with an emphasis on broadband communication systems such as those based on wireless and optical fiber transmission. Candidates should have a demonstrated interest and record of accomplishment in the design, fabrication and testing of analog and digital integrated circuits at the transistor level. They should have a good knowledge of semiconductor integrated circuit technology, and it is essential that their research interests include a strong experimental component. They must also be interested in developing and teaching both undergraduate and graduate courses in electronic circuit design, with an emphasis on nonlinear analog circuits and circuits for high-speed communications. The appointment will be at the Assistant or Associate Professor level. Please send a complete resume, a publication list, and the names of at least five references to Professor Bruce Wooley, Search Chairman, Department of Electrical Engineering, CIS-206, Stanford University, Stanford, CA 94305-4070. Applications should be received by July 1, 1993. Stanford University is an equal opportunity/affirmative action employer and especially encourages applications from women and minority candidates.

Electrical Engineering: Geneva College is seeking candidates for a tenure-track position in electrical engineering. Candidates should have their highest degree in electrical engineering, Ph.D. preferred. Professional experience is also desirable. Geneva is a church-controlled college in the evangelical and Reformed traditions and seeks faculty members who share that perspective and want to develop their teaching and scholarship within that framework. Women and members of ethnic minorities are encouraged to apply. For more information, contact Dr. J. Gidley, Engineering Search Committee, Geneva College, Beaver Falls, PA 15010.

Chairperson, Electrical Engineering. The Department of Electrical Engineering at The Ohio State University is seeking nominations and applications for the position of Department Chairperson, effective sometime after July 1, 1993. The position is for a tenured appointment at the rank of Professor in the Department of Electrical Engineering. The qualifications desired include a doctorate in electrical engineering or a closely related field; a strong commitment to all aspects of education at both the graduate and undergraduate levels; recognized stature in research, with a distinguished record of scholarly publications; involvement in professional society activities; demonstrated leadership and organizational abilities in either government service, industry, or academia; and a strong interest in enhancing the Department's reputation. The Department consists of 43 faculty members, a research and support staff of 42, and over 700 undergraduate and 270 graduate students. Traditionally, there has been a strong emphasis on both effective teaching and outstanding research. External funding for the latter, which is in excess of $5.5 million annually, involves support in analog and digital VLSI circuits, computer engineering, control, electric power systems, electromagnetics, electro-optics, manufacturing and robotics, signal and image processing, and solid-state microelectronics. Commensurate with this level of research activity, the Department has impressive research and teaching laboratory facilities and extensive local computer resources enhanced by the Ohio Supercomputer Center, located on campus. Interested applicants should submit resumes, which include the names of at least three references, to Professor Umit Ozguner, Chairman, Search Committee, Department of Electrical Engineering, The Ohio State University, 2015 Neil Ave., Columbus, Ohio 43210-1272, (614) 292-5940, csearch@ee.eng.ohio-state.edu. The Ohio State University is an Equal Opportunity/Affirmative Action Employer. Qualified women, minorities, Vietnam-era veterans, disabled veterans, and individuals with disabilities are encouraged to apply.

Case Western Reserve University - The Department of Electrical Engineering and Applied Physics invites applications for a tenure track junior faculty position beginning August 1993. Applicants must have an earned Ph.D., excellent academic credentials and the ability to teach at both the graduate and undergraduate levels. The successful candidate will be expected to initiate and carry out independent research. Particular need exists for a faculty member in the solid state area. Applications will be accepted until the posi-

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tion is filled. Send resume including names and addresses of at least three references to: Donald E. Schuele, Acting Chairman, Department of Electrical Engineering and Applied Physics, Case Western Reserve University, Cleveland, OH 44106 Telephone (216) 368-4088. Case Western Reserve University is an Equal Opportunity/Affirmative Action Employer.

Electrophysiology Position - Division of Cardiology: Long Island Jewish Medical Center (LIJ) invites applications for research Electrophysiology position. Adjunct appointment at Hofstra University possible for qualified candidates. Doctoral degree required. Successful candidate will have strong background in signal processing and computing, and background in bio-mathematical modeling or working knowledge of neural network theory and implementation. Ability to independently design and implement systems essential. Position involves evaluation and processing of large amounts of data in new and innovative ways. Must be effective team leader and direct and oversee the research of several graduate students and post-doctoral fellows. Salary commensurate with qualifications and experience. Send resume and three references to: Dr. Steven J. Evans, Director, Cardiac Electrophysiology, LIJ, Room 2135, New Hyde Park, NY 11042. Telephone: (718) 470-7333; Fax: (718) 343-9762. Long Island Jewish Medical Center is the Long Island Campus for the Albert Einstein College of Medicine. An Equal Opportunity Employer.

Post-Doctoral Research Positions. The Air Force Institute of Technology (AFIT) is inviting qualified applicants for two post-doctoral research positions. One appointment is available in each of the Department of Electrical and Computer Engineering and the Department of Mathematics and Statistics, beginning in the fall of 1993. The successful candidates will participate in the development of extensions of the theory of variable-length signal processing in the context of wavelet and Fourier analyses and/or applications of wavelet analyses to achieve more powerful and flexible tools for discrimination, detection, speaker identification, co-channel speaker separation, noise reduction, anti-jamming, etc. Computational facilities are the highest caliber and are continually being expanded. Minimum requirements are (1) U.S. citizenship; (2) a recent Ph.D. in a discipline appropriate for the position sought - electrical engineering or computer science for one position - mathematics, applied mathematics or statistics for the other position; and (3) expertise in Fourier analysis, wavelet analysis, and signal processing. Salary is commensurate with qualifications. AFIT is located in southwestern Ohio, just outside Dayton, offering the advantages of affordable housing, good schools and possible cooperation with the Air Force Laboratories at Wright-Patterson Air Force Base. Applicants should: (1) send a curriculum vitae, including a list of publications; (2) send reprints of best publications; and (3) have three people send letters of recommendation to one of the following, as appropriate for the position sought: Dr. Bruce W. Suter, AFIT/ENG, Bldg 640, 2950 P St., Wright-Patterson AFB OH 45433-7765 or, Major Gregory T. Warhola, AFIT/ENG, Bldg 640, 2950 P St., Wright-Patterson AFB OH 45433-7765. AFIT is an equal opportunity, affirmative action employer.

Hong Kong Baptist College. A Government-Funded Institution of Higher Education offering Undergraduate and postgraduate Degree Programmes. The College is now seeking candidates who have good teaching, research and/or industrial experience to support the Applied Computing Degree Course: Real-time systems development, microcomputer systems, computer interfacing and robotics. Applicants should possess a relevant PhD, or higher degree with substantial experience in industrial automation. For more information, please direct your enquiries by email to recruit@comp.hkbc.hk. Terms of Appointment: Salary on University Lecturer Scale, range: HK$343,680 to HK$574,140 p.a. (-approx. US$1=HK$7.8). Appointments are normally made either on Superannuable Terms or Gratuity Terms (15%). Generous benefits include vacation leave, medical and dental benefit for appointee and family and children's education allowance. Air passages and housing are also provided where applicable. Application Procedure: Please send by fax or by mail complete CV, transcripts, a recent photo, together with names & addresses of three referees to the Personnel Section, Hong Kong Baptist College, 224 Waterloo Road, Kowloon, Hong Kong [Fax: (852) 339-7371]. Deadline for application is 30 May 1993.

Princeton University, Post-Doctoral Research Fellow in Network Protocols and Modeling. Dept. of Electrical Engineering, Princeton University invites applicants for a Post-Doctoral Research Fellow with specialization in network protocols and modeling. Prospective candidates should have a Ph.D. in E.E. or C.S. with in-depth knowledge in most of the following subjects: OSI and GOSIP, TCP/IP, light weight protocols, and database access performance. Appointment is for one year with the possibility for extension. Salary depends on experience. Candidates should send resume and three letters of reference to Prof. Hisashi Kobayashi, B-323, Dept. EE, Princeton University, Princeton, NJ 08544. Princeton University is an Equal Opportunity Employer.

Faculty Position, Environmental Remote Sensing, Stanford University. The Department of Electrical Engineering and the School of Earth Sciences seek applicants for a joint, tenure-track appointment in Environmental Remote Sensing. We invite applications from those with interests in the passive and active electromagnetic, extended visible, or other techniques pertinent to understanding of Earth's physical environment. Potential areas of focus include the atmosphere, oceans, polar areas, and land surfaces, with emphasis on methods by which these can be studied remotely in the context of Earth systems and Earth as a planet. The successful applicant will teach and conduct advanced research in remote sensing instrumentation, techniques, and applications, and will supervise graduate students drawn from engineering and earth sciences. An appointment will be made at the junior level, tenure track. Applicants will be evaluated on basis of their creativity, background and ability to understand and discover underlying physical phenomena, ability to develop and lead an independent research program, potential or demonstrated ability to motivate and guide students and to teach, and excellence of performance to date. Review of applications will begin June, 1993. Please send a letter of application, complete resume, a publication list, and the names of at least five references to: Prof. Leonard Tyler, Search Committee Chairman, Department of Electrical Engineering, Stanford University, California 94305-4055. Stanford University is an Equal Opportunity/Affirmative Action employer and especially encourages applications from women and minority candidates.

The Department of Electrical Engineering at the State University of New York College at New Paltz invites applications for a tenure track faculty position at the Assistant/Associate Professor level. Applicants should have a Ph.D. in EE or a related field. Candidates should be able to teach a variety of undergraduate courses including circuits, electronics, communication systems, & control systems; and should also be interested in pursuing research & have the ability to develop & teach senior & graduate level courses within their research discipline. Resumes including visa status (if applicable) and the names, addresses & tele numbers of three refs should be sent to: Dr. Owen Hill, Dept. Chr., Box 10, The College at New Paltz, NY 12561 & will be considered starting 4/15/93. AA/EOE. The College at New Paltz seeks to maintain a community of culturally diverse scholars.

University of Florida, Faculty Position in Electrical Engineering at the Graduate Engineering and Research Center at Eglin Air Force Base. The Department of Electrical Engineering invites applications for a tenure-track position in the area of electro-optics. The academic rank will depend upon the qualifications of the successful candidate. Possible areas of interest include, but are not limited to: holography, interferometry, optical communications, optical signal processing, optoelectronics and integrated optics. Familiarity with acoustooptic cells, spatial light modulators and especially high speed microwave circuits would be especially useful. Applicants must possess a doctoral degree and show a strong record/commitment to graduate teaching and experimental research in electro-optics. The person selected must be able to qualify for a DOD secret security clearance. The position is available starting in the summer of 1993. Resumes and the names and addresses of four references should be sent to Professor Ramu V. Ramaswamy, Chairman, Faculty Search and Screen Committee, Electrical Engineering Department, 216 Larsen Hall, University of Florida, Gainesvile, FL 32611-2044, phone (904) 392-9265, e-mail: Ramu@eng.ufl.edu. Application deadline is May 31, 1993. The University of Florida is an equal opportunity/affirmative action employee and women and minorities are encouraged to apply. According to Florida law, applications and meetings regarding applications are open to the public upon request.

Position Announcement, Electrical Engineering Department, Bucknell University. Bucknell University invites applications for three tenure-track positions, two at the Assistant Professor level and one may be at the Associate Professor level. One individual will also be selected as the recipient of the T. Jefferson Miers Fellowship which will provide support for summer research and professional development. Successful applicants will be able to show promise as teachers and researchers in the areas of signal processing, optics, computer hardware, microprocessors, and VLSI. Responsibilities include course and laboratory development and supervision of design projects. A Ph.D. (by the time of appointment) in electrical and/or electrical/computer engineering is required. Bucknell University is a private university emphasizing quality undergraduate education in engineering and the liberal arts. Review of applications will begin immediately and continue until the positions are filled. Please send applications to: Maurice F. Aburdene, Electrical Engineering Department, Bucknell University, Lewisburg, PA, 17837. Women and members of minority groups are especially encouraged to apply.

The University of Tennessee Space Institute, Faculty Position in Engineering Management. Applications are invited for a tenure-track faculty position at the rank of Assistant or Associate Professor in the Engineering Management Program for Fall 1993. The successful candidate will be expected to develop and teach engineering management courses at the Masters level, be capable of attracting and directing research at the Masters level, be a contributor for formulating and proposing strategies for future directions, and be able to effectively interact with industry and faculty. The successful candidate will be able to demonstrate a well-balanced background which includes experience in quantitative analysis as well as technical and general management in industry. A BS degree in engineering or applied science, and a PhD degree in industrial engineering, engineering management or a closely related area is required. A track record or demonstrated potential in research and publication related to engineering management, and the capability to attract funded research must be demonstrated. Demonstrated potential for good teaching. Engineering Management is a concentration of the Industrial Engineering post-graduate Program of the University of Tennessee, Knoxville. Students in the program reside at any of the campuses in the UT system or study at-a-distance from work locations. The successful candidate will be required to be innovative and adaptive in developing and executing new methods of instructional design and delivering in a mixed environment of live, interactive TV, and video tape. Send resume and names of references from industry and academia to: Dr. Max L. Hailey, Interim Program Chairman, Engineering Management, The University of Tennessee Space Institute, Tullahoma, TN 37388. UTSI is an EEO/AA/Title IX/Section 504/ADA employer.

The University of Tennessee Space Institute, Faculty Position in Engineering Management. Applications are invited for a tenure-track faculty

position at the rank of Associate Professor or Professor in the Engineering Management Program for Fall 1993. The successful candidate will be expected to provide leadership in developing and teaching engineering management courses at the Masters and PhD levels, be capable of attracting and directing research at the Masters and PhD levels, be a major contributor for formulating and proposing strategies for future directions, and be able to effectively interact with industry and faculty. The successful candidate will be able to demonstrate a well-balanced background which includes experience in quantitative analysis as well as technical and general management in industry. A BS degree in engineering or applied science, and a PhD degree in industrial engineering, engineering management or a closely related area is required. An impressive track record in research and publication related to engineering management, and the capability to attract funded research must be demonstrated. Engineering Management is a concentration of the Industrial Engineering postgraduate Program of the University of Tennessee, Knoxville. Students in the program reside at any residence or work location. The successful candidate will be required to be innovative and adaptive in developing and executing new methods of instructional design and delivering in a mixed environment of live, interactive TV, and video tape. Send resume and names of references from industry and academia to: Dr. Max L. Hailey, Interim Program Chairman, Engineering Management, The University of Tennessee Space Institute, Tullahoma, TN 37388. UTSI is an EEO/AA/Title IX/Section 504/ADA employer.

University of Minnesota, Department of Electrical Engineering, Faculty Position in Optics. The Department of Electrical Engineering at the University of Minnesota, Twin Cities campus is seeking an outstanding candidate in the field of optics and optical engineering. The level of appointment will be determined by the applicant's qualifications and experience. The candidate is expected to conduct a vigorously funded research program and teach both undergraduate and graduate courses. Primary consideration will be given to candidates with backgrounds in electrooptic system design, medical optics, holography, and/or laser and non-linear optical systems. The requirements of this position include an earned Doctorate in an appropriate discipline at the time of the appointment and outstanding academic and research records. Applicants should send their curriculum vitae, a list of publications, and the names of at least three references to: Professor Marshall Nathan, Chairman, Faculty Recruiting Committee, Department of Electrical Engineering, University of Minnesota, 200 Union Street S.E., Minneapolis, MN 55455. The last date for receiving applications will be May 15, 1993, for the position available September 16, 1993. The University of Minnesota is an equal opportunity educator and employer.

Graduate Research Assistants. The Center for Microelectronics Research (CMR) at the University of South Florida is seeking graduate research assistants to support research activities in the areas of VLSI/ULSI/WSI/MCM architecture, circuit design, rapid prototyping, test and design automation; microelectronic materials and defects and semiconductor processing and manufacturing. Successful applicants will be required to pursue an MS or Ph.D. program in E.E., C.S.&E., or Engineering Science. Stipends are available in the range of $12K to $19K (half time) for a full calendar year beginning August 1993 or January 1994 with tuition waivers available. Applicants must have an excellent academic record and a minimum of a Bachelors degree in an appropriate discipline. U.S. Citizenship is a requirement for most current and anticipated positions. CMR has an expanding program of funded research and seven new research laboratories. USF is an Affirmative Action/Equal Opportunity Employer. Resumes to Dr. Earl Claire, Director, CMR/USF, M/S ENG 118, 4202 E. Fowler Avenue, Tampa, FL 33620.

University of Texas at Arlington. In anticipation of future openings, the Department of Electrical Engineering invites applications for Assistant Professors in the areas of telecommunications, energy systems, electronics and control. A Ph.D. in electrical engineering is required. Please send resume to Professor Robert Mitchell, Department of Electrical Engineering, University of Texas at Arlington, Box 19016, Arlington, Texas 76019-0016. The University of Texas at Arlington is an Equal Opportunity/Affirmative Action Employer.

Electrical Engineer. The College of Staten Island/CUNY seeks candidates for a substitute faculty position (assistant or associate professor) to teach in an ABET accredited baccalaureate program in Engineering Science. Ph.D. in Electrical Engineering required, with specialization in signal processing, computer engineering, communications, or electro-optics preferred. To start: September 1, 1993. Send curriculum vitae and names and addresses of three references by April 30, 1993 to: Prof. P. Razelos, The College of Staten Island/CUNY, 130 Stuyvesant Place, Staten Island, N.Y. 10301. Equal Opportunity/Affirmative Action Committee.

Princeton University: The Department of Electrical Engineering invites applications for a full time, tenure-track, junior or senior faculty position. The areas of particular interest are Computer Architecture, Parallel Processing, and other closely related disciplines in Computer Engineering. Please send a complete resume, a description of research and teaching interests and names of three references to Professor Stuart Schwartz, Chairman, Dept. of EE, Princeton University, Princeton, NJ 08544. An Affirmative Action/Equal Opportunity Employer.

Display Research Scientist - Senior Research Fellow, entry-level position for applied physicist or engineer. Successful applicant to establish research program on liquid crystalline display technology, write proposals for extramural research funds and support of graduate students, participate in graduate programs and in group research on liquid crystalline materials (NSF ALCOM Center). Closing date for applications: June 1, 1993. Submit resume, summary of research or reprints, and names of three professional reference to Dr. J.W. Doane, Director Liquid Crystal Institute, Kent State University, P.O. Box 5190, Kent, OH 44242-0001. Equal Opportunity/Affirmative Action Employer.

Monterrey Institute of Technology, Mexico City Campus, (ITESM), is looking for candidates for positions as professors in Electrical Engineering, Electronics Engineering, Computer Science, and Digital Systems. Minimum requirements: Ph.D. or M.S. in Electrical Engineering with specialty in Electronics, Computer Science, Digital Systems, or Information Systems. Ability to teach in Spanish. Competitive salaries, good benefits, travel to and from Mexico. Starting date - August 1, 1993. Send resume, letter of intent and transcript to Dr. France J. Pruitt, U.S. Representative, P.O. Box 34430, Bethesda, MD, 20827, Tel (301) 493-4982, Fax (301) 530-2461.

Government/Industry Positions Open

Electrical Engineer for NE Ohio machine parts manufacturer, to analyze & evaluate component configuration & materials of switch gears & circuit breakers for redesigning, rebuilding & upgrading; design & build remanufacturable parts & new replacement parts; design high & middle voltage disconnect switches & high voltage circuit breakers in SF6; design programs for contact systems in disconnect switches & circuit breakers. Applicants will qualify with 2 yrs. exp. in above duties & a B.S. in Electrical Engineering (must be able to speak, read & write electrical engineering terms in Spanish). Must be willing to travel to Mexico 3-5 times/yr. up to 3 wks./trip, for a total of 30% of the time. M-F, 8:AM - 5:PM, $35,720/yr. Must have proof of legal authority to work permanently in the U.S. Send resume in duplicate (No Calls) to J. Davies, JO #1200979, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216.

Traction Electrification/Substation Engineer. Develop and produce designs and specifications for traction electrification systems, including power supply and distribution, traction power substations, overhead catenary systems, and cathodic protection systems; direct consultants, analyze proposals, administer contracts, test systems related to electric traction in rail transit; perform engineering analysis and write technical reports. Bachelor of Arts in electrical engineering or equivalent Professional registration; other education or degrees and experience may be considered a substitute for Bachelor degree. Five years experience as an accomplished electrical engineering professional, including three years experience in rail transit area directly applicable to the duties and responsibilities of the position offered, and experience in installation of overhead catenary systems (OCS) required. Forth (40) hours per week, $58,000 per year, Portland, Oregon. Applicant must have legal authority to permanently work in the United States. Send your resume to Employment Division, Attention Job Order No. 5550430, 875 Union Street, N.E., Room 201, Salem, Oregon 97311.

Manager, Product and Engineering Division. Manage the Engineering and Product Development Group for the design, development and support of electronic cash registers (ECR), Point of Sale systems (POS), Back Office Software Systems (BOSS), and ECR and POS peripherals and components. Define specifications for operating systems for all of the vertical retailing industries consisting of the food marketing industry; hospitality industry; and general, mass and specialty retailing industry. Organize, assign and coordinate projects and goals using automated project management system. Maintain UL, FCC and worldwide requirements for product approvals. Phase-in projects to Manufacturing and Marketing groups. Manage all group department managers. Report to the President and participate in executive staff meetings. Rqrmnts: B.S. Electronic Engineering; 5 yrs. exp. in job offered or in related occupation as R & D Manager (POS industry) [If exp. in related occupation, up to 1 yr. out of the 5 may be as product development Engineer of POS systems]; must have 4 yrs. exp. w/ programming languages Assembly, Forth & C and software programs PSN Project Scheduler, ORCAD, AutoCAD and Quatro, and 2 yrs. exp. w/mechanical hardware design & electronic Printed Circuit Board layout and design (all may be included within other exp. required); must have proof of legal authority to work permanently in the U.S. 40 hrs/wk.; 8:30am - 5p.m.; $49,495/yr. Send 2 copies of resume to: IL Dept. of Employment Security, 401 S. State St.-3 South, Chicago, IL 60605, Attn: J. Aschenbrenner, Ref. #6109-A. No Calls. An employer paid ad.

Senior Network Systems Engineer for firm in NE Ohio. To design network engineering and support of hardware and software in a multi-protocol environment for various projects for NASA/Lewis Research Center; also to perform analysis, design, and monitoring of tests on existing broadband fiber networks; as well as to assess technology in Broadband ISDN, frame relay and deployment of migration of existing subsystems to a broadband fabric. In connection with carrying out the objectives of migrating to a Broadband network, responsibilities will also include engineering the local distribution of a Switched Megabit Data Service (SMDS) provided by an interchange carrier and its subsequent transition to a national gigabit network infrastructure. Must have Ph.D. (or ABD) in Electrical Engineering. Academic program must include one graduate-level course each in the following areas: Advanced Computer Communication Networks, Optimization Theory, Dynamic Optimization, Stochastic Modeling, Reliability Engineering, Simulation Techniques, Advanced Switching Theory, Digital Signal Processing, and Image Processing. Must be conversant with Broadband ISDN concepts, specifically with fiber protocols, TCP/IP, IEEE 802.6 standards and protocols, and ATM transport techniques. [These skills may be substantiated by academic letter(s) of reference; and/or by employer testimonial(s); and/or by publication(s).] Must have 6 mos experience as electrical engineer or (computer) systems engineer. Experience must have included satellite communications; and Wide Area Networks. Experience may be gained before, during, or after degree. 40 hrs/wk, 8:00am-5:00pm, $45,000/yr. Must have proof of legal authority to work indefinitely in U.S. Send resume & course transcript in duplicate to J. Davies, JO# 1200980, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

CLASSIFIED EMPLOYMENT OPPORTUNITIES

Electrical Engineer for NE Ohio restaurant franchisee to analyze & evaluate control systems of operations including security control; design, implement & maintain electronic security control using video camera, video frame grabber board, computer technology, & hardware tools such as converters, alarm systems, rectifiers, etc.; develop electric & technical improvements by building & maintaining interface to various control systems & power supplies using schematic drawings; travel to all 20 operations in Ohio & New York area, mostly by car, 20 times/year, 2-10 days/trip, for approximately 40% of the time. No exp. required in above duties, but applicants will qualify with a B.S. in Electrical Engineering (must have completed a project-minimum two academic quarters- designing an electronic security control system utilizing video camera, video frame grabber board, & computer technology) and 3 months exp. as an Assistant Control Systems Engineer (exp. must be in building & designing interface to various control systems & power supplies & preparation of schematic drawings). Exp. may be gained before, during or after degree. Must be willing to travel in Ohio & New York, mostly by car, at least 20 times/year, 2-10 days/trip, for approximately 40% of the time. Must have proof of legal authority to work permanently in U.S. M-F, 8:AM-5:PM, $33,155/year. Send resume in duplicate (No Calls) to J. Davies, JO #1200982, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216.

National Computerization Agency (NCA), Korea. The NCA was established in 1987 to spearhead a nationwide effort to develop the National Information Network. NCA has successfully completed the initial stage of its missions, which includes the development of masterplan for national computerization, information systems auditing, standardization of IT infrastructure for National Information Network, the promotion of the IT application and professional consultation of technical and policy issues for the government. For the next stage of informatization at the national level, the NCA will initiate a new project called Next Generation National Information Network. The NCA is seeking a number of professionals in the areas of information systems and networking. Applicants must have a Ph.D. and several years' experience in related work. Reviews of applications will continue until the positions are filled. Applicants should send a resume, three references to: Dr. Sang H. Kyong, President, National Computerization Agency, 80 JuksunDong, JongroGu, Seoul 110-756, Korea, Fax:+82-2-733-6037, E-mail:shkyong@henl.nc.re.kr

Mathematician. The U.S. Army Research Office is seeking an individual to aid in the administration of an extramural research program in the field of mathematical sciences with emphasis on mathematical aspects of information and control theory. Duties include analyzing and evaluating proposals and reports; maintaining liaison with contractors; analyzing contractor performance; maintaining familiarity with the status of research programs relevant to Army needs; and disseminating program policies, procedures and results to interested parties. This is a Federal civilian position at the GS-12 grade level ($40,298 - $52,385 per annum). Applicants must possess a doctoral degree in or directly related to the mathematical sciences. For further information and application forms, contact U.S. Army Research Office, Attn: AMXRO-CP, P.O. Box 12211, Research Triangle Park, NC 27709-2211, Ph: 919-549-4212. Open Until Filled. An Equal Opportunity Employer. U.S. Citizenship Required.

Engineer, Senior CAD: Develop physically based quantitative models for IC fabrication processes, including dopant diffusion, ion implantation & thermal oxidation; collaborate with technology development & application groups to design & implement process physics experiments; analyze experimental data & develop CAD models; implement models into 2D/3D process simulation software; maintain & support process simulation software. Ph.D. in Physics or Electrical Engineering or Materials Science. Academic project/research background in: IC fabrication process modeling; diffusion modeling development & simulation in semiconductors; point defect based dopant diffusion mechanisms; point defect distribution, formation & evolution of extended defects & their interaction with dopant diffusion; process simulation programs for IC manufacturing process simulation; IC process & simulation tools; numerical analysis of systems of coupled differential equations; large software programs; computer architecture; electronic materials; UNIX, C & FORTRAN. $4,700/mo.; 40 hrs./wk. Place of employment and interview: Aloha, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job Order #5550445, 875 Union Street, N.E., Room #201, Salem, OR 97311. The company is an equal opportunity employer and fully supports affirmative action practices.

Engineer, Senior Design: Design power & clock distribution for present & next-generation microprocessors; conduct network simulation & modeling; evaluate metal migration at high current densities; assess speed, area, power & reliability tradeoffs relating to circuits & computer architecture; develop & implement algorithms. Ph.D. in Electrical and/or Computer Engineering. Academic project/research background in: CMOS/BiNMOS VLSI circuit & logic design, simulation, layout & modeling; power & clock distribution & electromigration effects for microprocessors; transmission line theory & effects for high speed logic circuitry; computer aided circuit design; VLSI CAD tools, including MAGIC & SPICE; software design & development; network algorithm design & development; solid state device theory; computer architecture; UNIX. X-Windows & C. $4,600/mo.; 40 hrs./wk. Place of employment and interview: Hillsboro, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job Order #5550446, 875 Union Street, N.E., Room #201, Salem, OR 97311. The company is an equal opportunity employer and fully supports affirmative action practices.

Director of Research and Development. Bachelor's in elec. eng. or physics & 5 yrs.' progressive exp. managing major development projects & clinical testing for critical care monitoring & diagnostic products for anesthesiology & intensive care. Exp. must include: hands-on development of electrochemical sensors, software for embedded systems, microprocessor hardware & high impedance front-end analog circuitry; & preparation of applications to & pro-actively representing the interests of the company to nat'l. & int'l. regulatory agencies including the FDA (Food & Drug Admin.) & ISO (Int'l. Standards Org.). Manage & direct major development projects & clinical testing for critical care monitoring & diagnostic products for anesthesiology & intensive care. Particular develop. products include electrochemical sensors, software for embedded systems, microprocessor hardware & high impedance front-end analog circuitry. Provide tech. eng. directions to research & develop. staff, & review all elec. eng. & related tech. documents for the product design & mfg. processes. Develop strategic goals which maximize the integration of co.'s tech. abilities with identified market needs. Resp. for regulatory affairs relating to the nat'l. & int'l. mkt. of products, including the preparation of applications & reports to nat'l. & int'l. regulatory agencies, incl. the FDA & ISO & pro-actively representing the interests of the co. to these agencies through such activities as attending public committee meetings & advocating the co.'s position with respect to prod. complaints issues & tech. issues. Accountable for major operational budget. 40 hrs./wk. Overtime as required. 8:00 a.m.-5:00 p.m. Salary range: $85,800 - $103,260/yr. plus bonus dep. on exp. & qual. Send resumes to: 7310 Woodward Ave., Rm. 415, Detroit, MI 48202. Reference No. 8993. Employer Paid Ad.

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Project Electrical Engineer. Provide engineering design expertise in the field of industrial power systems. Interface directly with client to determine their needs and provide them with high quality designs. Supervise CAD operators in production of engineering drawings. Promote consulting firm to present and potential future clients. Engineering design experience in industrial power systems is essential. Knowledge of computer operations and ability to work with others in team concept required. BSEE or equal and 4 years experience in job offered. Annual salary $36,000. Apply at the Texas Employment Commission, Corpus Christi, Texas, J.O. #6736866 or send resume to the Texas Employment Commission, TEC Building, Austin, Texas, 78778, J.O. #6736866. Ad Paid by an equal opportunity Employer.

Otsuka Electronics (U.S.A.) Inc. has an immediate opening for the following position: Clinical Applications Scientist: Responsibilities for this position include design and development of pulse sequences and methods for clinical applications for Magnetic Resonance Imaging (MRI) systems. Minimum M.S. but PhD preferred in Physics, Chemistry, or related field with 2+ years MRI applications experience as well as familiarity with C-programming in a UNIX environment. Previous experience in manufacturing environment desirable. Send resume to Director of Human Resources, 2555 Midpoint Drive, Fort Collins, CO 80525. EOE. No Phone Calls Please.

RF Design Engineer. A consumer electronics company is seeking an individual to head up a development team. Candidate must have a strong RF background in design and layout. Must be familiar with programing GALS, PALS and PROMS. J-Deck file exp., Proficient with logic analyzers, machine language. CAD, math CAD. A background in CATV converter design and development would be a plus. Send resume with two references to: Everquest Inc., Engineering Div., 875 South 72nd St., Omaha, NE 68114.

Engineer, Senior Process: Conduct process & device characterization of uniform & non-uniform bandgap CMOS & Bipolar Junction Transistors; develop high performance CMOS & BiCMOS Logic processes; conduct DC & AC characterization of silicon devices & dielectrics; implement novel test structure design & device characterization methods; link & correlate device performance indicators to key process steps, including diffusion, oxidation, rapid thermal processing, thin film deposition, photo lithography & metallization. Ph.D. in Electrical Engineering or Materials Science. Academic project/research background in: semiconductor device design, fabrication, characterization, modeling & processing with an emphasis on determination of process conditions for optimum device performance; semiconductor device physics & processes for uniform & non-uniform bandgap materials; silicon processing & fabrication, including diffusion,

oxidation, rapid thermal processing, thin film deposition, photo lithography & metallization; novel device & material characterization techniques for correlation to critical process parametrics; identification of defect generating mechanisms & implementation of process fixes for yield improvement; VLSI circuit design & analysis; heterojunctions; UNIX & BASIC. $4,450/mo.; 40 hrs./wk. Place of employment and interview: Hillsboro, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job Order #5550448, 875 Union Street, N.E., Room #201, Salem OR 97311. The company is an equal opportunity employer and fully supports affirmative action practices.

Electrical Design Engineer: Design portable computers (notebook and pen-based) based on Intel's microprocessors, using Microsoft's "Windows for Pen" and Go Corporation's "Pen Point" with character recognition features. Tasks include architecture design for testability, schematics capture using "ORCAD", PCB (Printed Circuit Board) design using "PADS-2000", debugging and testing. It also includes preparing the product for mass manufacturing. Train technicians to troubleshoot notebook and pen-based computers. Develop new applications for existing products such as Ethernet, high speed modem, and external hard drive interface. Requires: (1) M.S. in Electrical Engineering, (2) Two years experience in the job offered or two years as a Design Engineer, (3) The required 2 years experience must include: design with Intel microprocessors, design for testability, schematics capture using "ORCAD", and PCB design using "PADS-2000". $35,500/yr., 40 hrs./wk., 8:30-5:00. Must have proof of legal authority to work permanently in the U.S. Send 2 copies of Resume, Diploma, and Experience Letters to: Illinois Department of Employment Security, 401 South State Street, 3 South, Chicago, IL 60605, Attn: Len Boksa, Ref. #V-IL-6535-B. No Calls. An Employer Paid Ad.

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Scanning
The Institute

Moore assumes volunteer activities post

Frank R. Moore has been named staff executive for volunteer activities, a newly created position. His responsibilities extend over the Institute's technical, regional, educational, professional, standards, and corporate activities.

Moore joins the IEEE from the Federal Networking Council, Washington, D.C., a privately funded group that he served as executive director. Before that, he was with IBM Corp., where he was a senior executive with nearly 30 years of experience.

Joining IBM in 1963, Moore worked in numerous management and technical positions, most notably information systems management. Until July 1992, he was technical assistant to the president of IBM's Multimedia and Education Division in White Plains, N.Y.

His appointment completes the Institute's new staff organization, which provides a closer alignment with the volunteer structure and an improved focus on business and product areas, noted IEEE general manager and executive director John H. Powers. Other recently named IEEE staff executives are Richard D. Schwartz, responsible for business administration, and Phyllis Hall, responsible for publications.

Videoconference tackles software

Complex overseas computer software markets and standards affected by recent political and economic changes will be the topics of a May 20 videoconference, "Delivering software products to the global marketplace," sponsored by the IEEE.

The three-hour videoconference, geared to software managers competing in global markets, will explore technical issues ranging from human-machine interfaces and product documentation conformance to international standards and worldwide manufacturing and design.

The cost is US $1800 for a corporate site and $850 for a university site with per-person rates available. For information, contact Robert Kahrmann, satellite and seminar manager, IEEE Educational Activities, Piscataway, N.J.; 908-562-5491; fax, 908-981-1686.

Maryland school's Future City wins

Asked how they would power a city in the year 2010, seventh- and eighth-graders from a Maryland school responded with a model of a city powered by hydroelectric and biomass energy sources. The students, from the Tilden Middle School in Rockville, Md., won the national finals of the first-ever National Engineers Week Future City competition, held by the U.S. Department of Energy in Washington, D.C.

The winning team consisted of students Emma Lincoln, Kevin Milans, and Matthew Smith; faculty advisor Gerry Klinglesmith; and engineer volunteer Steve Nieberding, who works for IBM Corp. The students' challenge was to engineer a city of the 21st century that is energy efficient, environmentally sound, cost efficient, and people oriented.

Five teams of finalists demonstrated and defended their projects before a panel of judges that included Martha Sloan, president of the IEEE and chair of National Engineers Week. Entries were evaluated on the basis of their computer design, city model, essay, and presentation.

Coming
in Spectrum

THIRD ANNUAL WORKSTATION FOCUS REPORT. The goal is to present a definitive, insightful report on today's workstations market. Topics covered will include the newest personal computers being offered to engineers; how much workstation performance each of three price ranges buys the user; and how some *IEEE Spectrum* readers squeeze the most out of standard systems. One expert explains what the current benchmarks truly tell us about what a workstation can do. Other experts deal with how best to share computer resources. Finally, a survey of the latest boards and subsystems, from mice to multimedia add-ons, suggests ways of improving a workstation.

THIN BLUE LINE. Solid-state lasers emitting blue-green light would have many uses, like quadrupling the bit density of compact discs. But defects and impurities mar crystal grown in bulk from II-VI materials. Now molecular beam epitaxy can deposit almost flawless layers, and laboratories around the world are perfecting the process.

HAMMING'S PORTRAIT. The Manhattan Project introduced computers to mathematician Richard W. Hamming, and he subsequently "sold" their revolutionary usefulness to his colleagues at Bell Laboratories. Still, it was out of frustration with the machines' mistakes that he invented his famous error-correcting code.

COMPUTER VIRUSES. What are the prospects of marginalizing these self-replicating pieces of code and moving them automatically toward extinction? A theory and recommended practice developed by *Spectrum*'s authors build on analogies with biological viruses and empirical data from hundreds of thousands of computer users and the life cycles of man-made computer plagues.

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